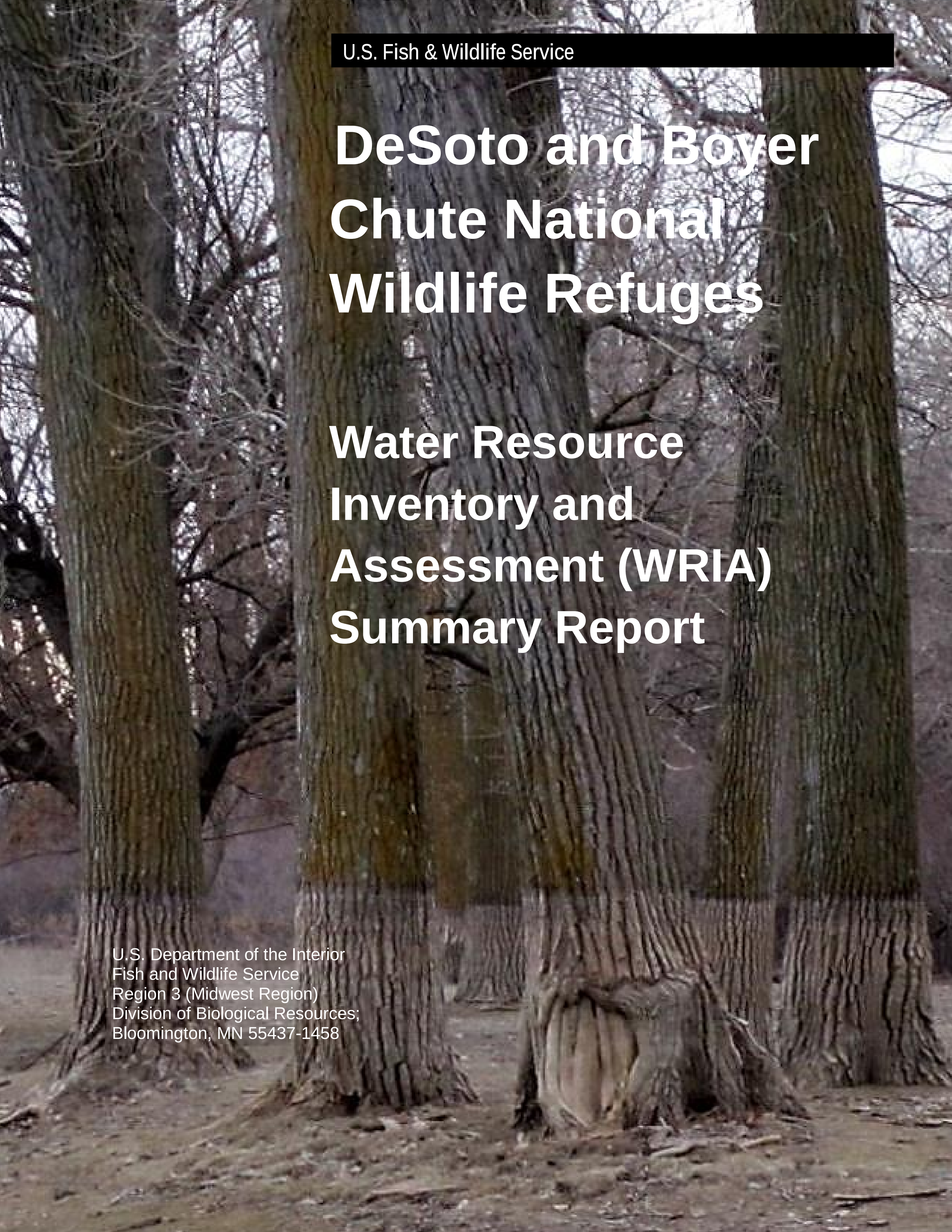


U.S. Fish & Wildlife Service

DeSoto and Boyer Chute National Wildlife Refuges

Water Resource Inventory and Assessment (WRIA) Summary Report

U.S. Department of the Interior
Fish and Wildlife Service
Region 3 (Midwest Region)
Division of Biological Resources;
Bloomington, MN 55437-1458

Cover photograph: Brian Newman (USFWS)

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

Authors:

Brian Newman
Mary Susan Gerlach
Josh D. Eash

Correspondence:

U.S. Fish and Wildlife Service
Region 3 (Midwest)
Division of Biological Resources
5600 American Blvd. West, Suite 990
Bloomington, MN 55437-1458
josh_eash@fws.gov

Authors' Note:

There are embedded links throughout this document within the table of contents and indicated by underlined text. A database of the presented data, additional data, documents and the referenced studies will be available as part of a digital document library housed on the Environmental Conservation Online System (ECOS). Geospatial data layers were obtained from the U.S. Fish and Wildlife Service, USGS seamless server, the Environmental Protection Agency, and the Missouri Spatial Data Information Services website.

Disclaimer:

(This page intentionally left blank)

Table of Contents

List of Figures

List of Tables

(This page intentionally left blank)

Executive Summary

DeSoto and Boyer Chute National Wildlife Refuges (DSBCNWR, refuges) are located within the historic floodplain of the Missouri River, where they provide important remnant habitat for migratory waterfowl. The anthropogenic modifications of the Missouri River over the course of the 20th century have changed its natural function dramatically, in an effort to tame the river. DSBCNWR water resource management attempts to mimic historical patterns and habitat diversity.

Findings

- There is a variety of methods to evaluate long-term climate trends at refuges, and there is a number of models, scenarios, and publications that address the current and anticipated trends in this part of the Midwest (e.g., Hayhoe et al. 2007, Union of Concerned Scientists 2009, National Oceanic and Atmospheric Administration 2013). Climate scenarios suggest that floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change. Rainfall has recently been, and is more likely to continue to be, concentrated into heavy events, with longer, hotter, dry periods intermingled. There is evidence of an increase in mean temperature values across the period of record. Winter and spring have shown increased temperatures, although no trend has been reported for summer and fall, and temperature trends are only statistically significant for annual and spring conditions.
- The expansion of wetland habitat to emulate pre-regulation flooding patterns is the preferred alternative within the DeSoto and Boyer Chute NWRs Environmental Assessment and Draft Comprehensive Conservation Plan (CCP) (U.S. Fish and Wildlife Service [USFWS] 2013) of four alternatives. Pre-regulation flooding patterns and floodplain connectivity was significantly different than current conditions. Over the course of the 20th century, the Missouri River and many of its natural functions were dramatically altered in an effort to tame the river. These human-caused changes to the Missouri River have dramatically impacted fish and wildlife habitat through the isolation of the Missouri River from its historic floodplain. In this part of the river, the likelihood of flooding has severely decreased with regulation and levee systems in place for the overwhelming majority of lands.
- The CCP identified planning priorities for DeSoto Lake (also called Desoto Bend Lake). They are: maximize quality of habitat for fish and aquatic species, investigate and clarify connectivity to the Missouri River, investigate drainage ditches, improve water quality, maintain healthy fishery, minimize resources required for lake management, strengthen partnerships, and minimize impact on refuge neighbors.
- DeSoto Lake is on the 303(d) list, because it only partially supports primary contact recreation (Class A), due to elevated turbidity and algal growth/Chlorophyll A. The condition of the lake is described as “aesthetically objectionable,” due to trophic state and visibility.
- DeSoto Lake has decreased in depth, as shown in bathymetric studies, which indicated a decrease in maximum depth from approximately 34.9 feet in 1967 to 21.98 feet in 2006 (Elliott et al. 2006). It is likely the 2011 Missouri River flood also resulted in substantial sediment delivery and subsequent decreases in depth.

- The Missouri River, from Council Bluffs to the Boyer River, does not support primary contact recreation due to levels of indicator bacteria that exceed state water quality standards. Also, aquatic life usage is only partially supported, based on information from local fisheries biologists, due to flow modification and habitat alterations in this segment of the Missouri River. Drinking water use is not supported due to levels of arsenic, which exceed state water quality criteria to protect human health from arsenic in fish and water. Despite the lack of designated usage support, the Missouri River has improved water quality in the last 30 years since the implementation of the Clean Water Act.
- A 29.4-mile segment of the Boyer River, ending at the confluence of the Missouri River, does not support primary contact recreation because of *Escherichia coli* (*E. coli*) levels. Water quality information for the Boyer River suggests high levels of nutrients and sediments, which are likely impacting aquatic life within the river. Although Boyer Chute NWR does not currently include any lands adjacent to the Boyer River, portions of the acquisition boundary do lie along the river. Any future acquisitions should consider the viability of the Boyer River as a water source for wetland restorations in the area.
- Boyer Chute has 15 permitted source water supply points, which is a combination of 10 groundwater permits and five surface water rights. Most surface water rights for Boyer Chute NWR are related to diversions from Deer Creek.
- Groundwater well information indicates that typical sub-surface groundwater levels were from 8–12 feet below grade. Elevated iron, manganese and dissolved solids were the primary issue of concern identified from water quality sampling conducted adjacent to Boyer Chute and anecdotal evidence from wells at the Refuges.

Recommendations

- Because of the apparent in-filling of the DeSoto Bend Lake, the refuge should consider options for maintaining deep-water refugia for fisheries, such as decreasing sediment inputs or dredging the lake. Nutrient reduction would be a secondary benefit of decreased sediment, as nutrients, such as phosphorus, often accumulate in bed sediments and can be recycled within a water body. Additionally, a significant drawdown and zooplankton population enhancement may be useful tools for managing potential eutrophic conditions, which may result from both agricultural drainage and internal recycling of nutrients.
- Re-route ditch water flows through existing wetlands to encourage nutrient reduction prior to the water entering DeSoto Lake. Ideal water retention times will vary seasonally based on nutrient loads but should be approximately one to two weeks.
- Work with the U. S. Army Corps of Engineers (USACE, Corps) to evaluate overbank flooding at Boyer Chute NWR. Due to down-cutting (incision) of the Missouri River, future reduced floodplain connectivity is likely for the chute and the main channel. Some locations may have greater connectivity from the 2011 flood, which should be evaluated and potentially armored to prevent further erosion. Where desired, bank heights could be potentially reduced to enhance connectivity to the river.
- Groundwater wells should be further evaluated for the potential of heavy metal contamination and excessive salts. Sampling should target nutrients, iron, and manganese. Future well installations should consider deeper aquifer access, which will potentially have improved water quality.

- To mimic historical patterns of the Missouri River, wetlands and DeSoto Lake could be managed to have sharp increases in water surface elevations in March and June. Water surface elevations would be allowed to increase in response to rain and slowly decrease into August or September. DeSoto Lake water level management alternatives are discussed in the CCP as well (USFWS 2013).
- Deer Creek is the source for surface water diversion rights at Boyer Chute NWR. Water quality information was not available for Deer Creek. If concerns exist about the quality of source water on the refuge, efforts should be made to evaluate water chemistry on Deer Creek to determine baseline water quality parameters and seasonal patterns.
- Explore opportunities to work with USACE, state, and local partners on potential levee setbacks on portions of DeSoto NWR. Although these efforts may require additional land acquisition, they would provide the opportunity to reconnect remnant hydrologic features on the landscape and align the levee system with topographic contours. Benefits would include increased floodplain connectivity, flood attenuation, and increased habitat for a wide variety of fish and wildlife.
- The installation of a spillway should be considered for DeSoto Bend Lake as an outlet to any future flood events that may inundate the refuge. Such a structure could be designed to both mitigate flood damages on the refuge and surrounding lands, as well as enhance management capabilities and connectivity with the river.

(This page intentionally left blank)

1. Introduction

This Water Resource Inventory and Assessment (WRIA) Summary Report for DeSoto and Boyer Chute National Wildlife Refuges (DSBCNWR, refuges) describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and advances recommendations regarding refuge water resources. This summary report synthesizes a compilation of water resource data contained in the national interactive online WRIA database. The information contained within this report and supporting documents will be entered into the national database for storage, online access, and consistency with future WRIAs. The database will facilitate the evaluation of water resources between regions and nationally. This report and the database are intended to be a reference for ongoing water resource management and strategy development. This is not meant to be an exhaustive nor a historical summary of water management activities at DSBCNWR.

The WRIA is a reconnaissance-level effort that will inventory and assess water rights, water quantity, water quality, water management, climate, and other water resource issues for each refuge. The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on Refuge System water quantity and quality in order to acquire, manage, and protect adequate supplies of water. Achieving a greater understanding of existing information related to refuge water resources will help identify potential threats to those resources and provide a basis for recommendations to the field and regional office staff. Through an examination of previous patterns of temperature and precipitation, and an evaluation of forward-looking climate models, the U.S. Fish and Wildlife Service (USFWS, Service) aims to address the effects of global climate change and the potential implications on habitat and wildlife management goals for a specific refuge.

The WRIA effort has been recognized as an important element of the NWRS Inventory and Monitoring (I&M) and is identified as a need by the *Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change* (USFWS 2010a, b). I&M is one element of the Service's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011).

WRIAs have been developed by a national team comprised of Service water resource professionals, environmental contaminants biologists, and other Service employees. The WRIA will be a useful tool for refuge management and future assessments, such as a hydro-geomorphic analysis of habitat and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan and Inventory & Monitoring Plan.

2. Refuge Information

DeSoto NWR was established on March 12, 1958. It was authorized by the Migratory Bird Conservation Act of 1929 (16 U.S.C. § 715d) for: "…use as an inviolate sanctuary or for other management purposes, for migratory birds." Later, the Refuge Recreation Act of 1962 (16 U.S.C. § 460k-1) identified additional purposes for which the refuge was suitable: "...(1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species…"

Boyer Chute NWR was established August 11, 1992 for the preservation and reclamation of Missouri River floodplain habitat critical to species living in riparian corridors and by authority of the Fish and Wildlife Act of 1956 (16 U.S.C. §§ 742a-754j).

The two refuges span roughly 13 miles of the Missouri River (figure 2-1), encompassing over 12,000 acres, located within the Missouri Alluvial Plain L4 Ecoregion (47d; Omernik 1995, 2004) and the Eastern Tallgrass Prairie & Big Rivers Landscape Conservation Cooperative (LCC).

The WRIA uses the 10-digit Hydrologic Unit Code (HUC-10) boundary as the potential zone of hydrologic influence and a relevant region for the collection of water quality and quantity information for the WRIA. HUCs are used to designate watersheds of various sizes and often represent the initial aggregate level of water quality and quantity information available from a variety of agencies (e.g., U.S. Environmental Protection Agency (USEPA) Surf your watershed [http://cfpub.epa.gov/surf/locate/index.cfm]). HUC boundaries are a successively smaller classification system based on drainage, adapted from Seaber et al. (1987). The smaller HUC-12 boundaries are also evaluated herein, if they contained the primary refuge source waters.

DeSoto NWR

DeSoto NWR is located in the Iowa counties of Harrison and Pottawattamie, as well as a small portion of Washington County, Nebraska. The refuge is approximately four miles east of Blair, Nebraska and six miles west of Missouri Valley, Iowa located along the reach of the Missouri River extending between the approximate river miles of 641.2 and 644.6 above the Mississippi River confluence.

The refuge encompasses 8,365 acres of the Missouri River floodplain in Iowa and Nebraska. Approximately 2,000 acres (maximum extent) of this refuge is managed as restored wetland habitats, for the benefit of fish and wildlife species. In addition to water control, the wetland management units are disked, burned, and mowed to maintain a diversity of plants that provide forage for migratory shorebirds, marsh birds, and waterfowl.

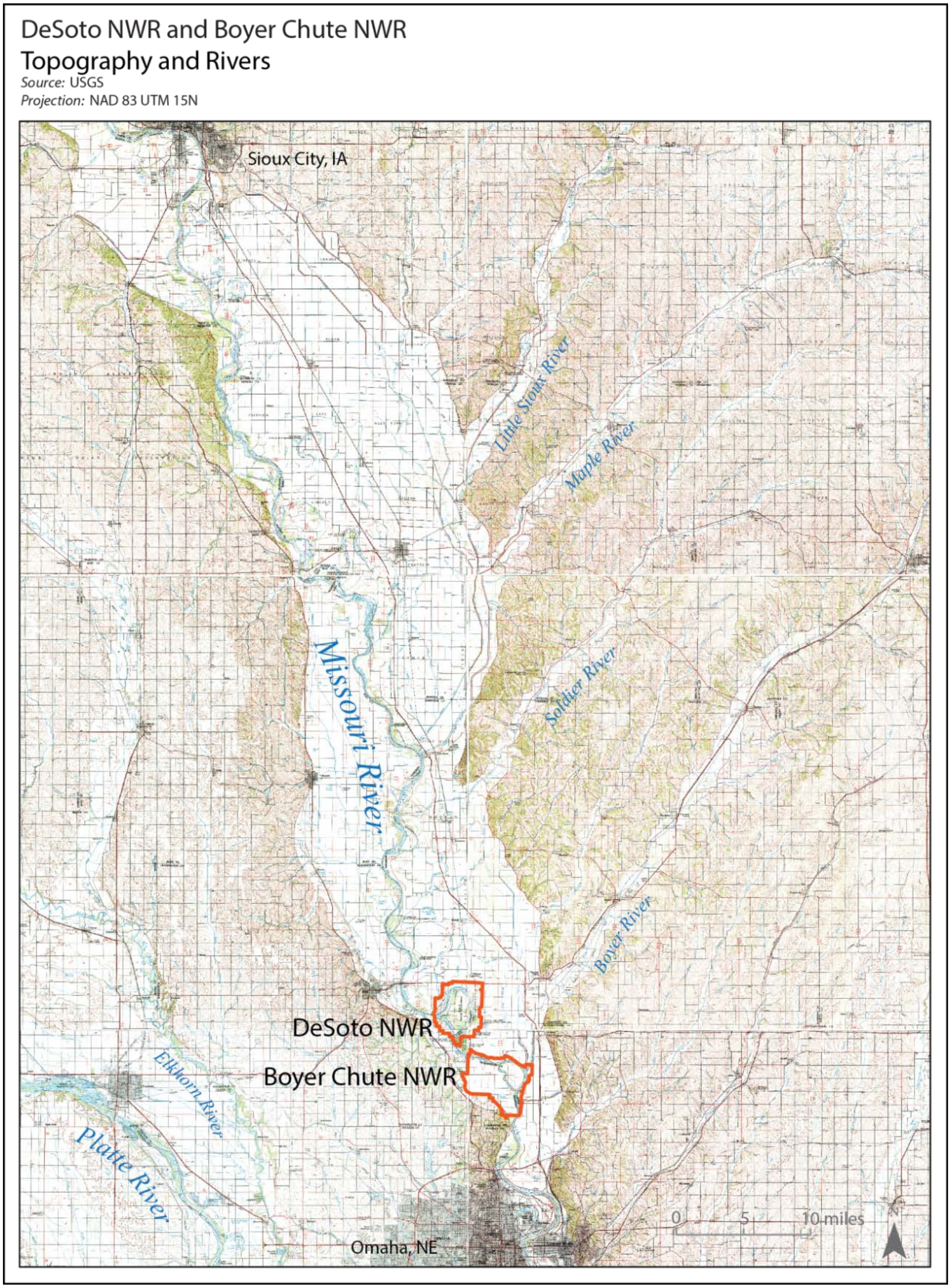


Figure 2-1: Location of DeSoto NWR and Boyer Chute NWR relative to local stream networks

The refuge was established astride a meander of the Missouri River, named DeSoto Bend, an area that was subsequently developed in conjunction with U.S. Army Corps of Engineers (USACE) channelization projects. Through congressional authorization, the USACE began work to cut off DeSoto Bend from the main stem of the Missouri River. In the fall of 1960, the USACE completed the cutoff, which established a 7-mile long man-made oxbow lake (DeSoto Lake) and is now the central water feature of the refuge. At normal water levels DeSoto Lake is approximately 850 acres in size. The Iowa side of the refuge is encompassed by a levee system encircling refuge lands on nearly all sides while the Nebraska side of the refuge contains only remnant segments of the original levee system.

The refuge acquisition boundary is located in the Honey Creek-Missouri River HUC-10 (figure 2-2; 1023000605) and all acquired units lie within the smaller Moores Creek-Missouri River HUC 12 (102300060502).

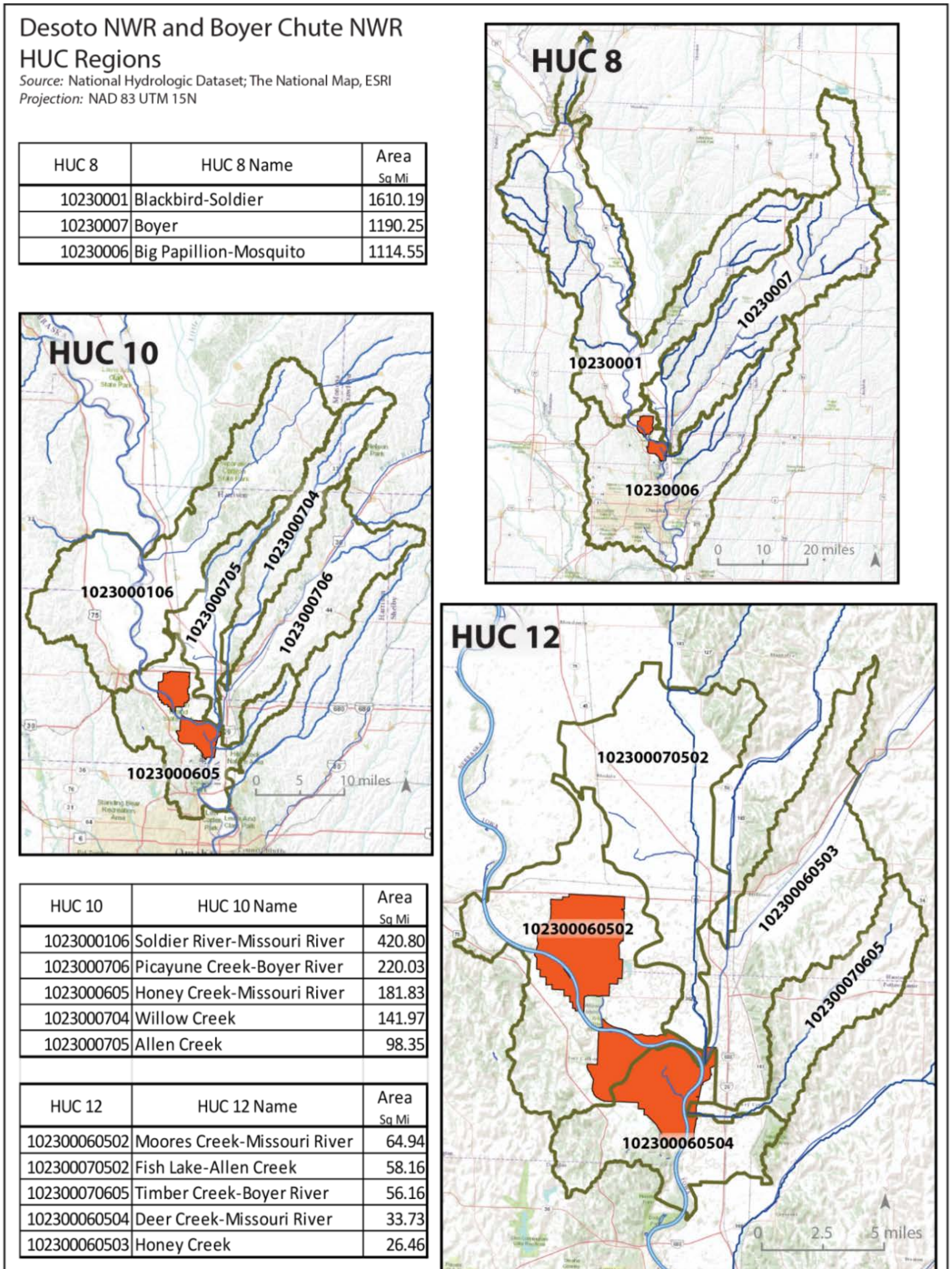
Boyer Chute NWR

Boyer Chute NWR is located in Washington County, Nebraska. The refuge is approximately two miles east of Fort Calhoun, Nebraska and extends along the reach of the Missouri River extending between the approximate river miles of 631.8 and 640.2 above the Mississippi River confluence (USACE 2009).

The refuge consists of 4,040 acres (approved acquisition boundary 10,010 acres) of floodplain woodland, tallgrass prairie, and wetland habitats, which benefit Missouri River fishes, migratory birds, endangered species, and resident wildlife. There is no levee system separating refuge lands from the Missouri River along this reach of the river.

The 2 ½ mile-long Boyer Chute (channel) paralleling the main flow of the Missouri River lies at the center of the refuge, for which it was named. The historic chute was a small side channel of the Missouri River, which eroded through the sediment delta of the Boyer River. In 1937, the chute was blocked by the USACE to enhance the Missouri's main navigation channel. In 1994, Boyer Chute became the first of many side-channel restoration projects on the Missouri River. The primary purpose of the Boyer Chute Restoration Project was to restore essential wildlife habitat without affecting navigation on the main stem of the Missouri River.

The refuge acquisition boundary is located in the Honey Creek-Missouri River HUC-10 (figure 2-2; 1023000605). While acquired units on the northern portion of the refuge lie within the smaller Moores Creek-Missouri River HUC-12 (figure 2-2; 102300060502), the majority of refuge lands are within the southern Deer Creek-Missouri River HUC-12 (figure 2-2; 102300060504).



HUC 8	HUC 8 Name	Area Sq Mi
10230001	Blackbird-Soldier	1610.19
10230007	Boyer	1190.25
10230006	Big Papillion-Mosquito	1114.55

HUC 10	HUC 10 Name	Area Sq Mi
1023000106	Soldier River-Missouri River	420.80
1023000706	Picayune Creek-Boyer River	220.03
1023000605	Honey Creek-Missouri River	181.83
1023000704	Willow Creek	141.97
1023000705	Allen Creek	98.35

HUC 12	HUC 12 Name	Area Sq Mi
102300060502	Moores Creek-Missouri River	64.94
102300070502	Fish Lake-Allen Creek	58.16
102300070605	Timber Creek-Boyer River	56.16
102300060504	Deer Creek-Missouri River	33.73
102300060503	Honey Creek	26.46

Figure 2-2: DeSoto NWR and Boyer Chute NWR Hydrologic Unit Codes for HUC 8, 10, and 12 boundaries

3. Natural Setting

The natural setting section describes the abiotic resources associated with the refuges, including the Missouri River, topography, geology, climate, and soils. These underlying, non-living components of an ecosystem provide the context on which water resources are constructed and managed.

The Missouri River

The Missouri River basin encompasses 529,350 square miles or nearly one-sixth of the entire United States. The river is one of the longest in the world, and the reach between Gavin's Point Dam and its confluence with the Mississippi River remains the longest free flowing river reach in the conterminous United States.

Over the course of the 20th century, the Missouri River and many of its natural functions were dramatically altered in an effort to tame the great river. The river, notorious for large floods, meandering channels and massive sediment transport at the beginning of the 20th century, bore little resemblance to its previously wild, free-flowing form by the end of the century. The river was channelized and leveed in an effort to facilitate navigation and protect floodplain communities and agricultural lands from the devastating floods. These activities were followed by the construction and management of a series of large main-stem dams and reservoirs designed to meet the demands of Missouri River water use (hydroelectric power, irrigation, navigation, recreation) and further protect against downstream flooding (USACE and USEPA 2002 page 54). In addition to the changes on the river itself, the entire watershed has been modified over time through land conversion, drainage, development and extensive management of flows (dams) from Missouri River tributaries. According to the 2006 National Land Cover Dataset (NLCD) (Fry et al. 2011), cultivated cropland is the dominant land cover type within the refuge boundaries (figure 3-1, table 3-1). Woody wetlands, grassland/herbaceous vegetation, open water, and emergent herbaceous wetlands also make up large portions of this area. Upstream watersheds are primarily dominated by cultivated crops, grassland/herbaceous vegetation, deciduous forest, pasture/hay, and some developed areas (table 3-2).

These human-caused changes to the Missouri River have dramatically impacted fish and wildlife habitat. Hydrologically, the isolation and management of rivers such as the Missouri from their historic floodplains have, in some cases, increased the likelihood of flooding through the reduction of upstream buffering areas (Poff et al. 1997).

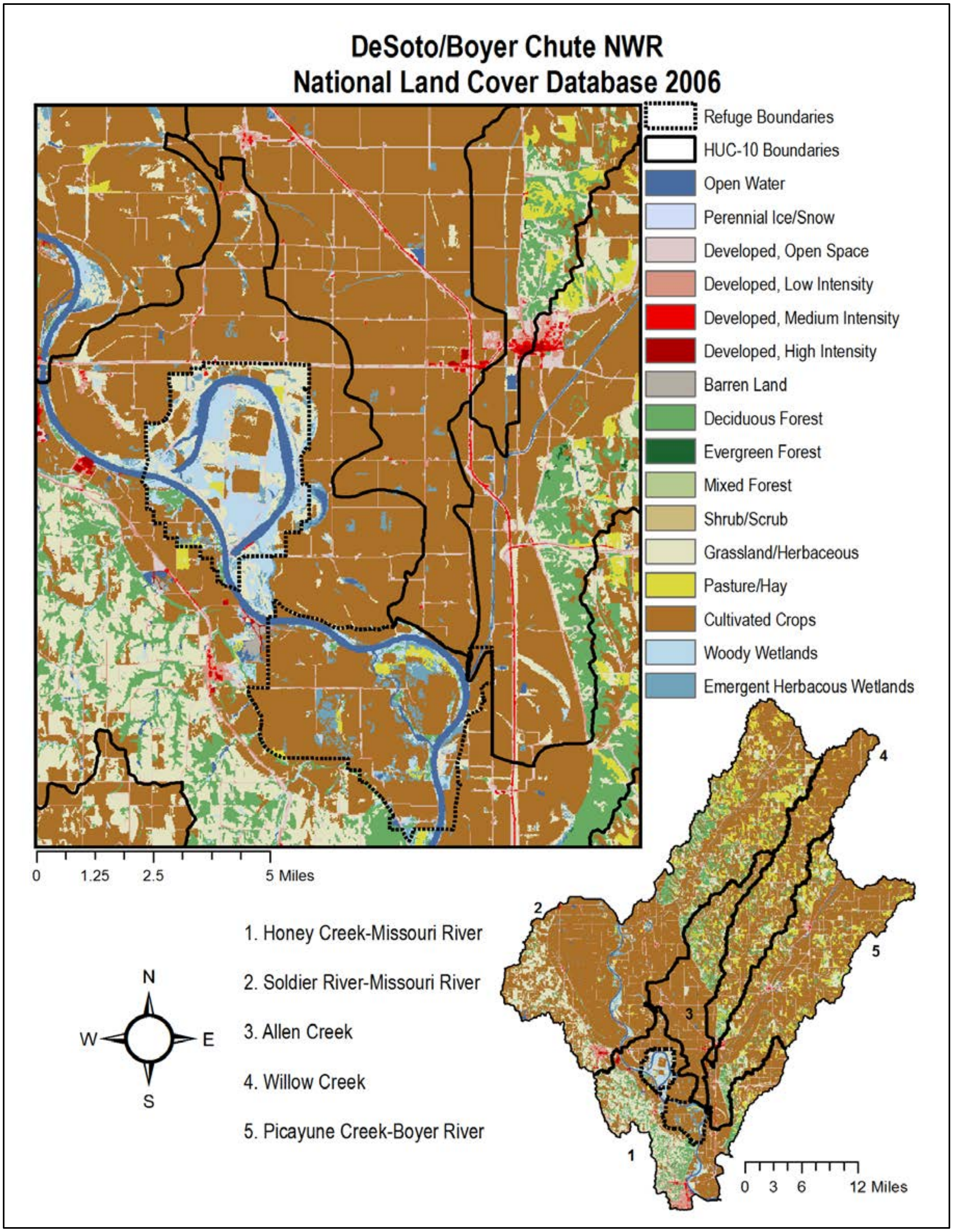


Figure 3-1: Land use of DSBCNWR and upstream watersheds from 2006 (NLCD)

Table 3-1: Land use statistics for DSBCNWR (NLCD 2006)

Land Use	DeSoto NWR		Boyer Chute NWR		Total	
	Acres	% of Refuges	Acres	% of Refuges	Acres	% of Refuges
Open Water	1191	14.2	892	9.0	2083	11.4
Developed, Open Space	440	5.3	186	1.9	626	3.4
Developed, Low Intensity	16	0.2	50	0.5	66	0.4
Developed, Medium Intensity	10	0.1	0	0.0	10	0.1
Deciduous Forest	157	1.9	188	1.9	345	1.9
Evergreen Forest	4	0.0	0	0.0	4	0.0
Scrub/Shrub	0	0.0	6	0.1	6	0.0
Grassland/ Herbaceous	1951	23.3	163	1.6	2114	11.5
Pasture/Hay	96	1.1	248	2.5	344	1.9
Cultivated Crops	1855	22.2	6705	67.4	8560	46.8
Woody Wetlands	2159	25.8	595	6.0	2755	15.0
Emergent Herbaceous Wetlands	489	5.8	906	9.1	1396	7.6
Total	8368	100	9941	100	18309	100

Note: NLCD only provides an approximate, 30m resolution representation of land cover boundaries and areas, and was created based on the classification of circa 2006 Landsat satellite imagery. The data does not necessarily reflect on-the-ground conditions, especially since land use around DSBCNWR has changed since the creation of the NLCD in 2006.

Table 3-2: Land use statistics for the Honey Creek-Missouri River and upstream watersheds (NLCD 2006)

Land Use	Honey Creek-Missouri River		Picayune Creek-Boyer River		Allen Creek		Soldier River-Missouri River		Willow Creek	
	Acres	% of Watershed	Acres	% of Watershed	Acres	% of Watershed	Acres	% of Watershed	Acres	% of Watershed
Open Water	3919	3.4	898	0.6	82	0.1	2462	1	118	0.1
Developed, Open Space	6055	5.2	8224	5.8	3719	5.9	12033	4	4825	5.3
Developed, Low Intensity	4994	4.3	1507	1.1	469	0.7	3159	1	236	0.3
Developed, Medium Intensity	1018	0.9	578	0.4	250	0.4	626	0	83	0.1
Developed, High Intensity	400	0.3	75	0.1	40	0.1	181	0	34	0.0
Barren Land	201	0.2	69	0.0	8	0.0	25	0	4	0.0
Deciduous Forest	13975	12.0	8367	5.9	6080	9.7	19736	7	5359	5.9
Evergreen Forest	12	0.0	67	0.0	127	0.2	347	0	40	0.0
Mixed Forest	1	0.0	0	0.0	0	0.0	0	0	0	0.0
Scrub/Shrub	9	0.0	6	0.0	0	0.0	4	0	0	0.0
Grassland/Herbaceous	23052	19.8	12593	8.9	4108	6.5	31641	12	6510	7.2
Pasture/Hay	1856	1.6	12541	8.9	2714	4.3	16879	6	7754	8.5
Cultivated Crops	53214	45.8	94707	67.3	44879	71.3	176638	66	65479	72.1
Woody Wetlands	5090	4.4	274	0.2	72	0.1	2224	1	89	0.1
Emergent Herbaceous Wetlands	2491	2.1	851	0.6	357	0.6	3165	1	287	0.3
Total	116287	100	140759	100	62905	100	269119	100	90817	100

Historical Fluvial Geomorphology

Historically, the lands that now comprise these refuges were located within the meander belt of the Missouri River, one of North America's most diverse ecosystems with abundant braided channels, riparian lands, chutes, sloughs, islands, sandbars, and backwater areas (figure 3-2). These riverine and floodplain habitats were created and maintained by erosion and deposition, which continuously reshaped the channel and floodplain. These waters sourced from the Rocky Mountains and the plains of North and South Dakota and were high in velocity and sediment, earning the Missouri River the nickname, "Big Muddy" (U.S. National Park Services "Rivers and Streams," [http://www.nps.gov/mnrr/naturescience/rivers.htm] Eliot and Jacobson 2006: Scientific Investigations Report 2006-5313 [http://pubs.usgs.gov/sir/2006/5313/]). Annual floods driven by snowmelt changed the course of the river, created shallow water areas, recharged wetlands, deposited nutrient-rich sediments on forests and prairies, and provided spawning habitat for fish. Summer low water enhanced the growth of wetland vegetation and sandbar habitats.

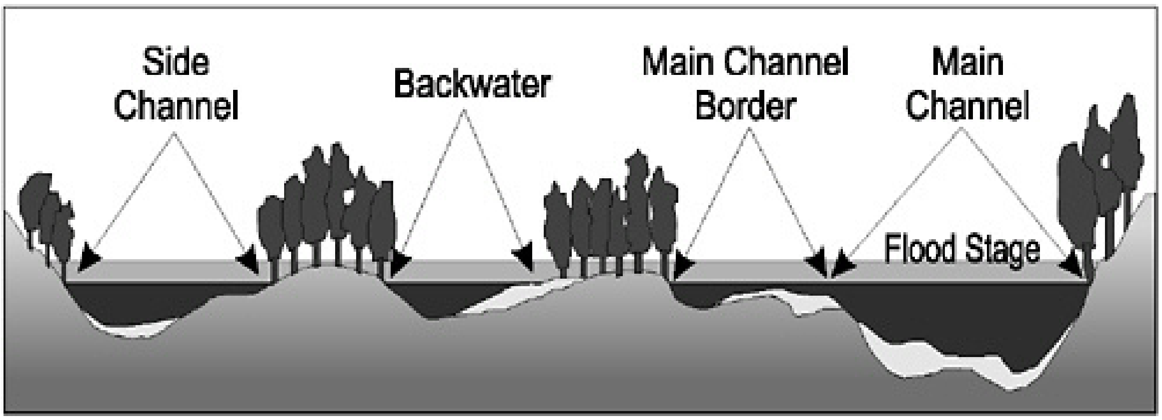


Figure 3-2: River channel types (from: USACE and USEPA 2002)

Prior to regulation of flows, large seasonal variations in flows (figure 3-3) helped provide the energy and hydrology for the abundant braided channels, chutes, sloughs, islands, sandbars, backwater areas, and floodplain wetlands. Pre-regulation descriptions of the Missouri River are available from the Lewis and Clark expedition and other sources (e.g., Ambrose 1997; Berner 1951; National Research Council [NRC] 2002).

The historic hydrology of the river included two seasonal flood pulses. The first, or March/April "rise," was caused by snowmelt in the Great Plains and breakup of ice in the main channel and tributaries. The second, or June rise, was produced by runoff from Rocky Mountain snowmelt and rainfall in the Great Plains and lower basin. The spring rise tended to be brief, lasting about one to two weeks, and was relatively localized. The summer rise lasted longer and inundated larger portions of the floodplain (NRC 2002). Late summer, fall, and winter were marked by declining stream flow and lower water levels which exposed the shoreline and many sandbar habitats generated during the flood season from sediment deposition.

The meandering nature of the Missouri River resulted in almost continual erosion and deposition of sediments, many times in extreme quantities. As an example, in 1879, it is estimated that 11 billion cubic feet of sediment were transported past St. Charles, MO. The main channel relocated over 2,000 feet in a single year, and stream banks eroded over 200 lateral feet during a single rise, which added to the sediment-rich water quality of the river. Downstream, these sediments impacted the Mississippi River and were deposited in the form of sandbars and islands as a dynamic reworking of floodplain topography. The entire Missouri River valley was available for lateral migration, varying from 1.5 miles to 17 miles in width, contained by large bluffs on both sides.

River Alteration

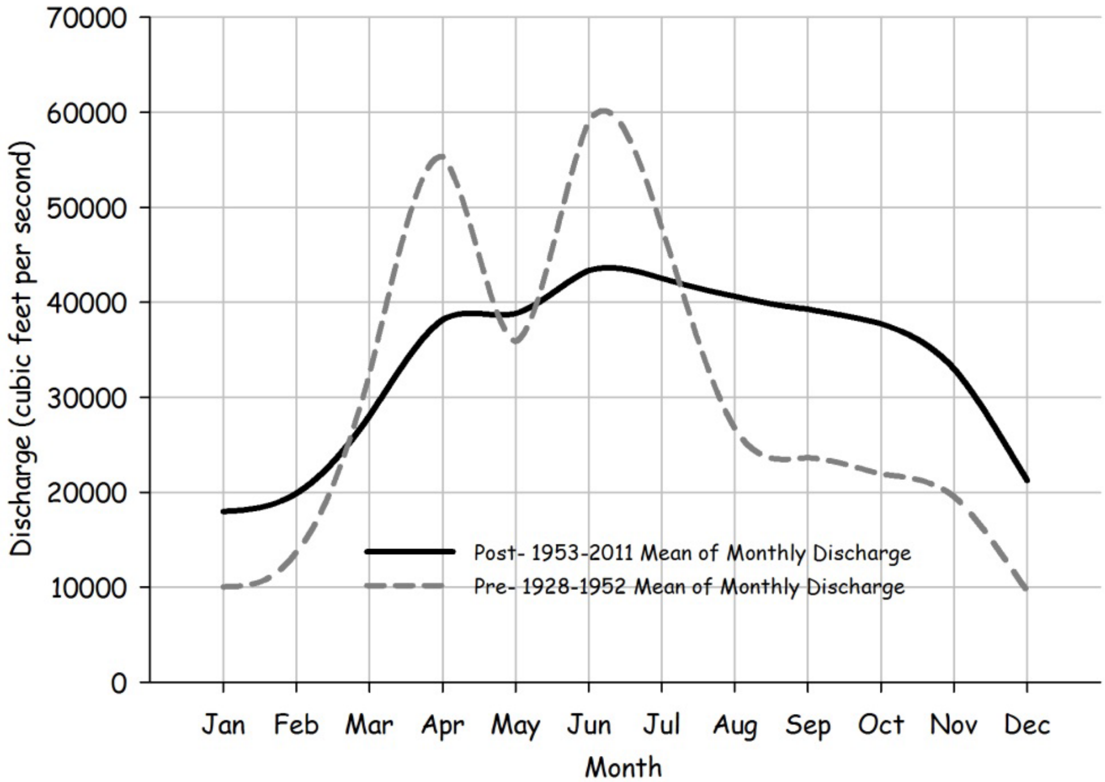


Figure 3-3: Monthly mean streamflow for Missouri River, pre and post regulation for U.S. Geological Survey (USGS) stream gage at Omaha, NE

In an effort to moderate the adverse effects of flooding, as well as meet demands for water supplies for irrigation and cities, hydropower production and a reliable navigation channel, Congress authorized a network of dams and bank stabilization projects that were constructed on the Missouri River main stem and tributaries. Although, discussions at the time and letters of support from various organizations suggest that this project would be multiple-use and more efficiently utilize the waters of the Missouri River for the benefit of wildlife (Hesse 1987).

In 1940, the first large dam on the Missouri River was completed at Fort Peck for the purposes of flood control and irrigation. The subsequent main stem dams were built following the broad outlines of the "Pick-Sloan Plan," a merger of already existing plans for the Missouri River basin developed by the USACE and the Bureau of Reclamation. Congress authorized the five other main stem dams on the Missouri River with the Flood Control Act of 1944, which were constructed by the USACE (1946–1966) to promote flood control, commercial navigation, and other related purposes. The Bureau of Reclamation assumed responsibility for water development along tributary streams and irrigation systems. By the mid-1950s, the downstream flow of water was under control. In addition, private entities and the U.S. Department of Agriculture built dams of different sizes on the tributaries, further affecting Missouri River water flow and sediment transport (NRC 2011).

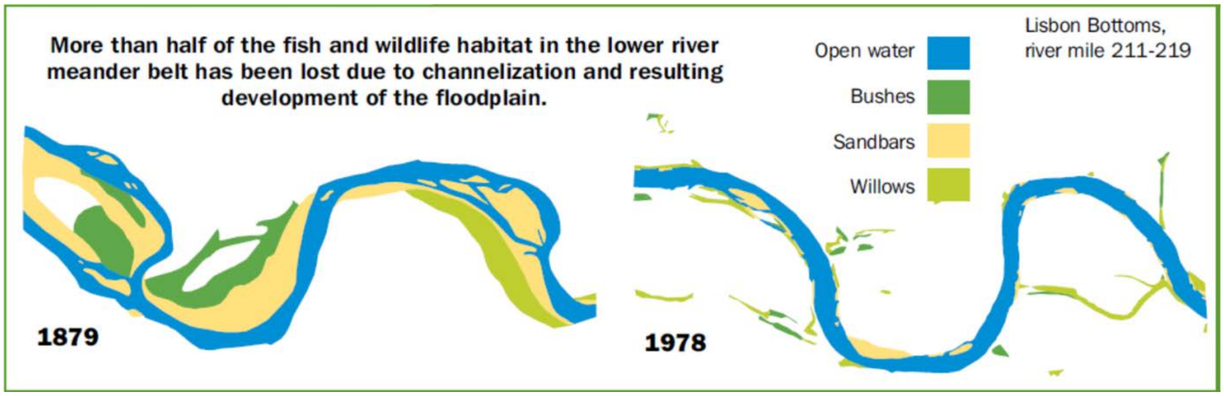


Figure 3-4: Typical changes in in habitat due to channel modifications, from Missouri River Natural Resources Committee Environmental Assessment brochure USGS-Biological Resources Division Environmental and Contaminants Research Center

In the 1945 Rivers and Harbors Act, Congress authorized the Missouri River Bank Stabilization and Navigation Project (BSNP). This act completed channelization of most of the Missouri River below Sioux City, Iowa—a process that had begun in the 19th century (figure 3-4)—via a combination of dikes, revetments, and other engineering structures. Today, the dams and bank stabilization projects are maintained and operated by the USACE, Bureau of Reclamation, and other entities. Current reservoir management objectives for the Missouri River basin system include flood control, hydropower generation, recreation, reliable municipal and irrigation water supplies, fish and wildlife, and maintenance of a commercial navigation channel.

In the process of impounding and channelizing the Missouri River, the Pick-Sloan dams and the BSNPs have provided numerous economic benefits. However, implementation of these projects also has had extensive and lasting implications for the river's hydrologic, sedimentary, and ecological systems (NRC 2011).

Wing dikes and revetments stabilize the riverbanks and narrow and focus the thalweg (deepest portion of the channel and fastest flow) to maintain a self-dredging navigation channel (Jacobson 2006). On adjacent alluvial land, extensive levee systems isolate the river from its floodplain.

The river engineering structures combined to create a narrow, swift, and deep channel from what was historically a shallow, shifting, braided river. The major changes of the river in the downstream State of Missouri resulted in an 8 percent reduction in channel length, a 50 percent reduction in channel water surface area, a 98 percent reduction in island area, and an 89 percent reduction in the number of islands (Funk and Robinson 1974). In addition, regulation and management of the Missouri River to maintain sufficient channel depth (nine feet) for April-November navigation depresses the March and June flood pulses, while augmenting late summer-autumn low flows.

Regulation of the Missouri River's flows also changed sediment transport and dynamics, greatly reducing the tons of sediment transported down river. The channel immediately downstream of the dams has degraded (deepened) by the low-sediment discharge from the dams. Channel degradation occurs from Sioux City to just above the Missouri River's confluence with the sediment-laden Platte River. Other areas show localized degradation, most notably in the Kansas City area and immediately downstream. Channel bed aggradation is happening in many places, especially near the confluence of the Missouri and Mississippi Rivers (NRC 2002 page 53).

Current Conditions

The alterations, infrastructure, and management of the Missouri River over the past century have profoundly changed the hydrology, function, and habitats of the river. The changes to the morphological and ecological processes that once sustained habitats and biotic communities along the river have resulted in a decline in species abundance, diversity, and distribution. The native species of fish were adapted to a relatively turbid, warmer environment with shallow habitat, and 96 percent of the fish species with populations in decline are native (Galat et al. 2005).

The USACE has primary jurisdiction over the main channel of the Missouri River. Wing dikes have been installed and maintained in the main channel, to direct flow away from banks and side channels. The sides of the river have been armored using riprap in sections. The construction and management of reservoirs within the upstream watershed have changed the previously dynamic flow regime of the River by suppressing the spring flood pulse and sustaining higher river flows throughout the summer and fall, thus limiting the movement and resource availability for those species that had adapted key phases of their lives to these types of hydrologic extremes.

Floodplain wetlands and shallow water habitat (SWH) typically inundated during annual flood events are now seldom recharged with water, nutrients, and connectivity to the river due to levees and channelization. Similarly, high elevation sandbar development and critical habitat for such species as the endangered Piping Plover and Least Tern have been prevented by the lack of high flows necessary to create them. Those sandbars that do exist have become covered with vegetation due to the lack of natural disturbance processes, such as periodic scour and inundation. Channelization has removed or altered many other important riverine habitat features including chutes, backwater areas, and tributary confluence areas, which are key habitats for species such as the endangered pallid sturgeon.

Despite upstream flow regulation, some flooding does occur on the Missouri River, especially along its lower reaches. The frequency of overbank flooding is somewhat reduced along many reaches by numerous agriculture levees constructed to prevent inundation during 5-year to 10-year events. Other privately constructed levees offer even less protection (Final Environmental Impact Statement for Proposed Expansion of Big Muddy National Fish & Wildlife Refuge, Missouri 1999). In fact, levees and channelization in some areas have constricted flood flows and thus magnified the elevation of flood peaks along sections of the river (Pinter and Heine 2005; USACE 2012). Large unregulated tributaries along the Missouri River still offer some variability to flow regimes. In some areas, the river still reconnects with part or, in the case of the 1993 and 2011 flood events, much of its floodplain on a periodic basis. However, most habitats within the meander belt of the Missouri River remain disconnected, and flood return intervals are substantially reduced from historical normals.

Other water quality concerns are impaired waters and fish consumption advisories along the Missouri River and its tributaries. Many of these water quality impairments are associated with non-point source runoff from the vast amount of agricultural land within the drainage basin, as well as legacy pollution from large population centers and industry.

Restoration Efforts

Today many state and federal agencies have taken steps to address habitat loss along the Missouri River. Beginning with the BNSP Fish and Wildlife Mitigation Project authorized under the Water Resources Development Act of 1986, agencies began focusing efforts on restoring and recovering habitats along the Missouri River. The mitigation project is aimed at restoring lands and habitats downstream of Sioux City, Iowa that were lost or damaged during channelization and bank stabilization activities. This project is authorized to purchase and restore up to 166,750 acres of land along the river for the benefit of fish and wildlife habitats. With the release of the Missouri River Biological Opinion in 2000, the U.S. Fish and Wildlife Service identified USACE management actions by which to protect and recover endangered species on the river, including flow management, habitat restoration, rearing and stocking, and continued study in an adaptive management framework. Using recommendations from the Biological Opinion, the USACE initiated the multi-partner Missouri River Recovery Program (Missouri River Recovery Program [MRRP], http://www.moriverrecovery.org/mrrp/MRRP_PUB_DEV.download_documentation?p_file=6071) aimed at achieving Missouri River ecosystem recovery goals.

MRRP efforts include projects designed to hasten or direct succession and diversity of floodplain habitats, several of which have occurred on refuge lands. The prevalence of private property adjacent to the river is one challenge to these efforts. Channel widening and chutes can only be accomplished where the USACE or a cooperating government agency (such as the Service) owns the adjacent property. Through the Corps' Mitigation Project, side channels have been constructed, such as at Boyer Chute NWR, to create SWH and reconnect the floodplain with the river. Some SWH work has been done within existing riverbanks to improve aquatic habitat next to the refuges. The work to develop more SWH includes notching dikes, rock placement to create reverse dike chevrons, and some bank excavation to create "rootless" dikes. Six chevrons have been constructed by the USACE in the DeSoto NWR stretch of the Missouri River channel to create sandbar habitat and nine in the Boyer Chute NWR stretch. On the east bank of the DeSoto NWR stretch of the Missouri River, twelve sites have been de-armored to encourage bank erosion. A regular dialogue between refuge management and the USACE is maintained, regarding riverine restorations on the Missouri River.

The restoration of SWH comes from one element of the reasonable and prudent alternative (RPA) outlined in the 2003 Biological Opinion, which requires the restoration of 20 percent of the SWH that existed prior to construction of the BSNP. SWH may be restored through flow management, channel widening, side channel chutes, manipulation of existing aquatic habitat, manipulation of summer flows, or combinations thereof as detailed on the MRRP SWH web page (http://moriverrecovery.usace.army.mil/mrrp/f?p=136:131:1056500852441::NO:::). A major component of the MRRP is meeting this element of the RPA. Almost all of the required SWH acres will need to be created by channel widening and the restoration of chutes and side channels. The result is the creation of SWH acres within the current top-width of the river and the creation of SWH by the conversion of terrestrial acres into new aquatic habitat.

There may be opportunities to explore with the USACE, state, and local partners to increase connectivity with the Missouri River and create additional SWH. Properly placed options, such as potential levee setbacks, spillways and low water crossings may meet multiple objectives. Although these efforts may require additional land acquisition in some areas, they would provide the opportunity to reconnect remnant hydrologic features on the landscape and align the infrastructure with topographic contours. Included in these options would be the installation of a multi-purpose water control structure / spillway for DeSoto Bend Lake. Such a structure could be designed to both mitigate flood damages on the refuge and surrounding lands, as well as enhance management capabilities and connectivity with the river.

Topography and flood inundation

High resolution bare-earth Light Detection and Ranging (LiDAR) data is currently available for the Iowa portions of DeSoto NWR from the Iowa Department of Natural Resources (DNR). In addition, the USACE (Omaha District) collected LiDAR for most portions of both refuges, following the 2011 flood event. The western portions of Boyer Chute NWR are the only areas of these refuges without LiDAR data available (figures 3-5 and 3-6).

Generally, the topography for the refuges is flat with subtle micro-topographical features apparent in high resolution data. There are a variety of topographic features, flow paths, and man-made structures that are apparent in the LiDAR data set. These features are a combination of historical Missouri River flow paths and anthropogenic modifications, such as levees.

Elevation on DeSoto NWR ranges from 987 feet (301.1 meters) above mean sea level (MSL) in low areas with ponds and in areas adjacent to DeSoto Lake, to 1,014 feet (309.2 meters) MSL on levees and roads. The map below shows that DeSoto Lake ranged in depth from 1.2–22.9 feet in 2006, with an average water depth of 7.6 feet, based on bathymetry data collected by the U.S. Geological Survey (USGS) (figure 3-7). The DSBCNWR CCP summarizes lake elevations based on the 2006 bathymetry data:

> *"…Overall, the west arm of the lake is substantially shallower (no point greater than 11.5 feet) than the central or eastern portions, and the deepest areas occur on the outside of the central and eastern sections, opposite sandbar deposition areas ... These depth features are consistent with those found in other bends of the Lower Missouri River and are a legacy of the bend's previous riverine conditions. Substrate in areas under four feet is primarily soft silt and fine sand; clay is rare. A considerable amount of soft silt is located near ditch outlets."*

In Boyer Chute NWR's authorized boundary, elevations range from 976 feet (297.6 meters) MSL in lower wetland areas and drainage ditches to 1,092 feet (332.9 meters) MSL on the small south-central points that rise onto the bluff.

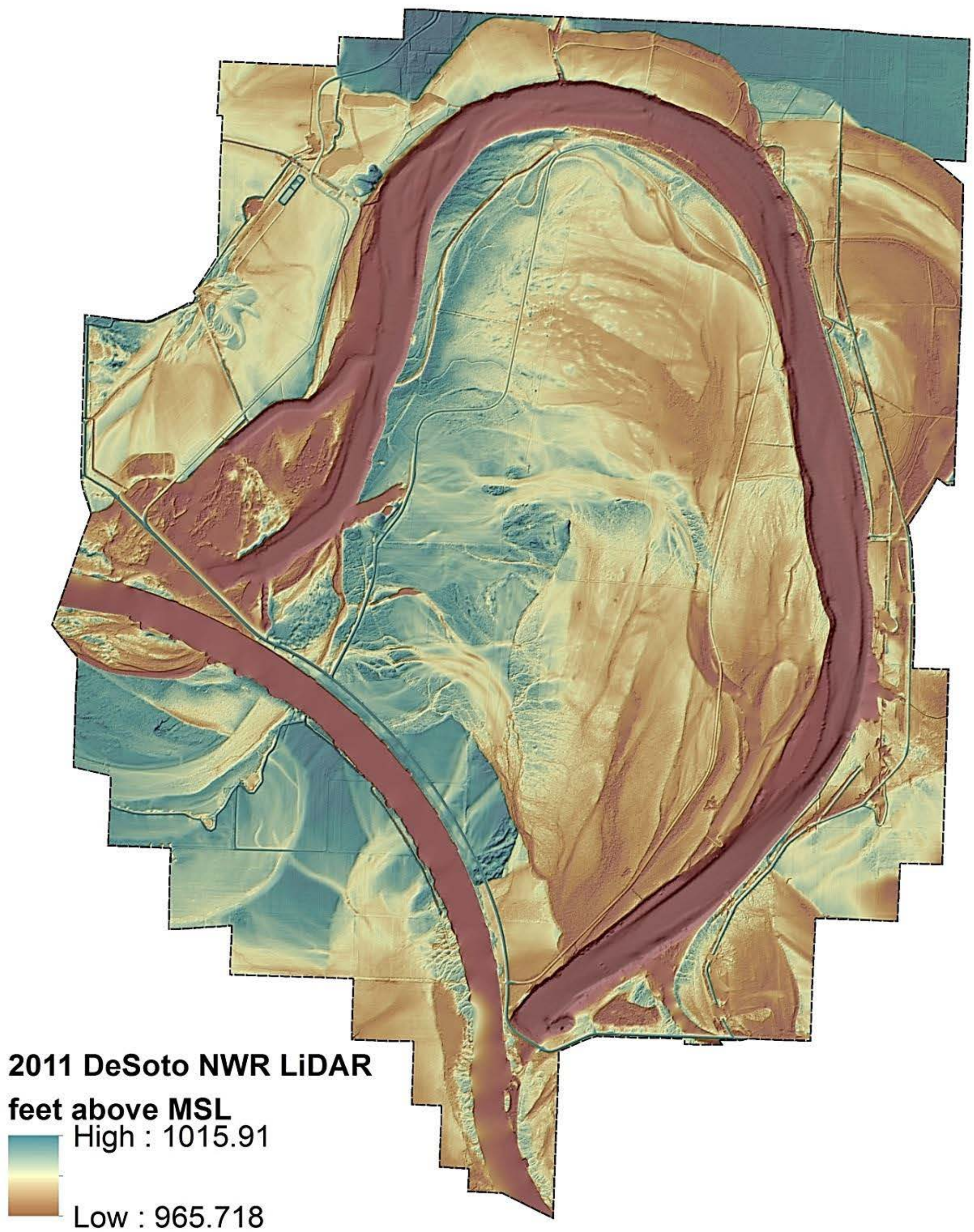


Figure 3-5: DeSoto NWR LiDAR Digital Elevation Model (DEM)

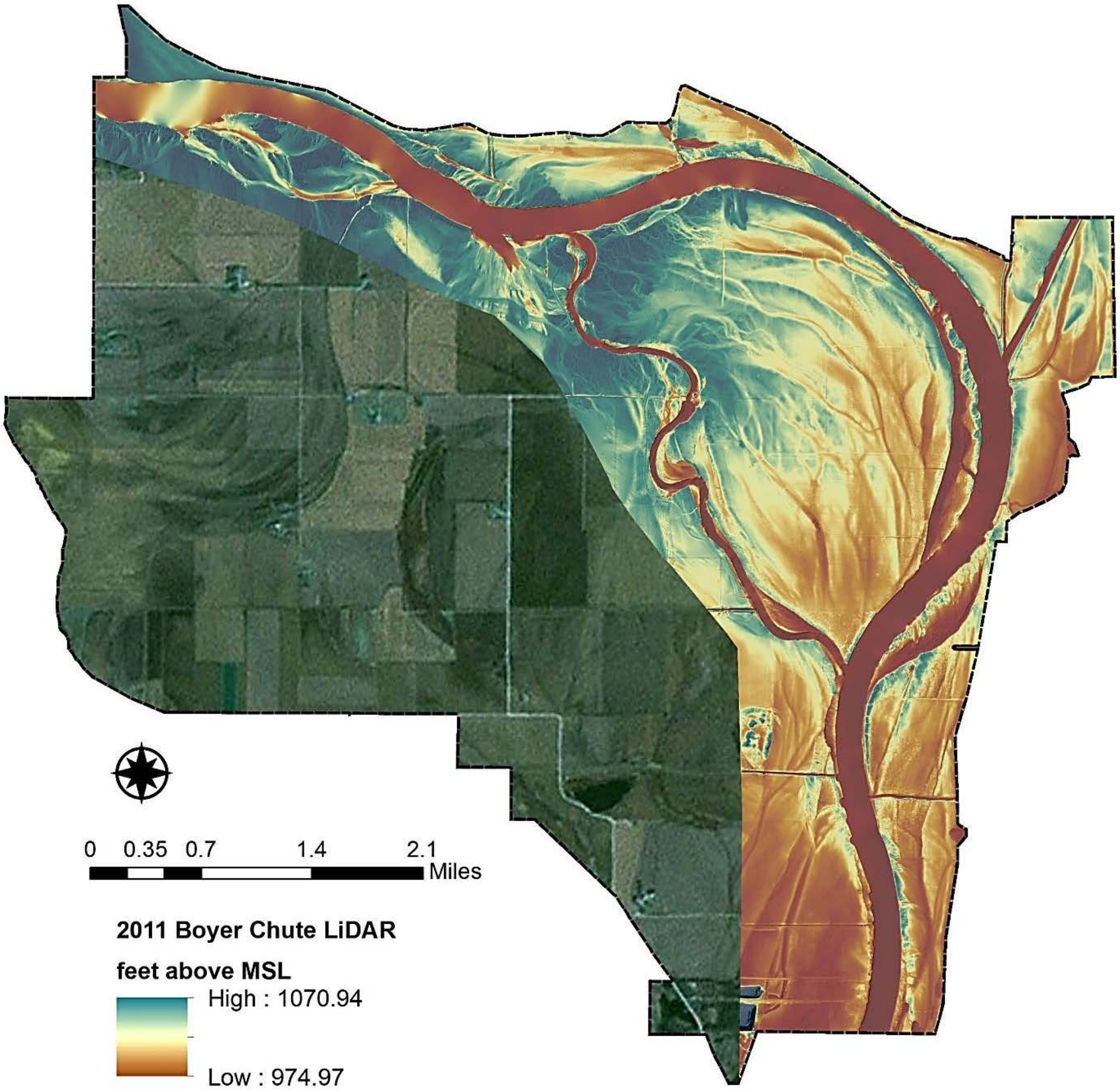


Figure 3-6: Boyer Chute NWR LiDAR DEM

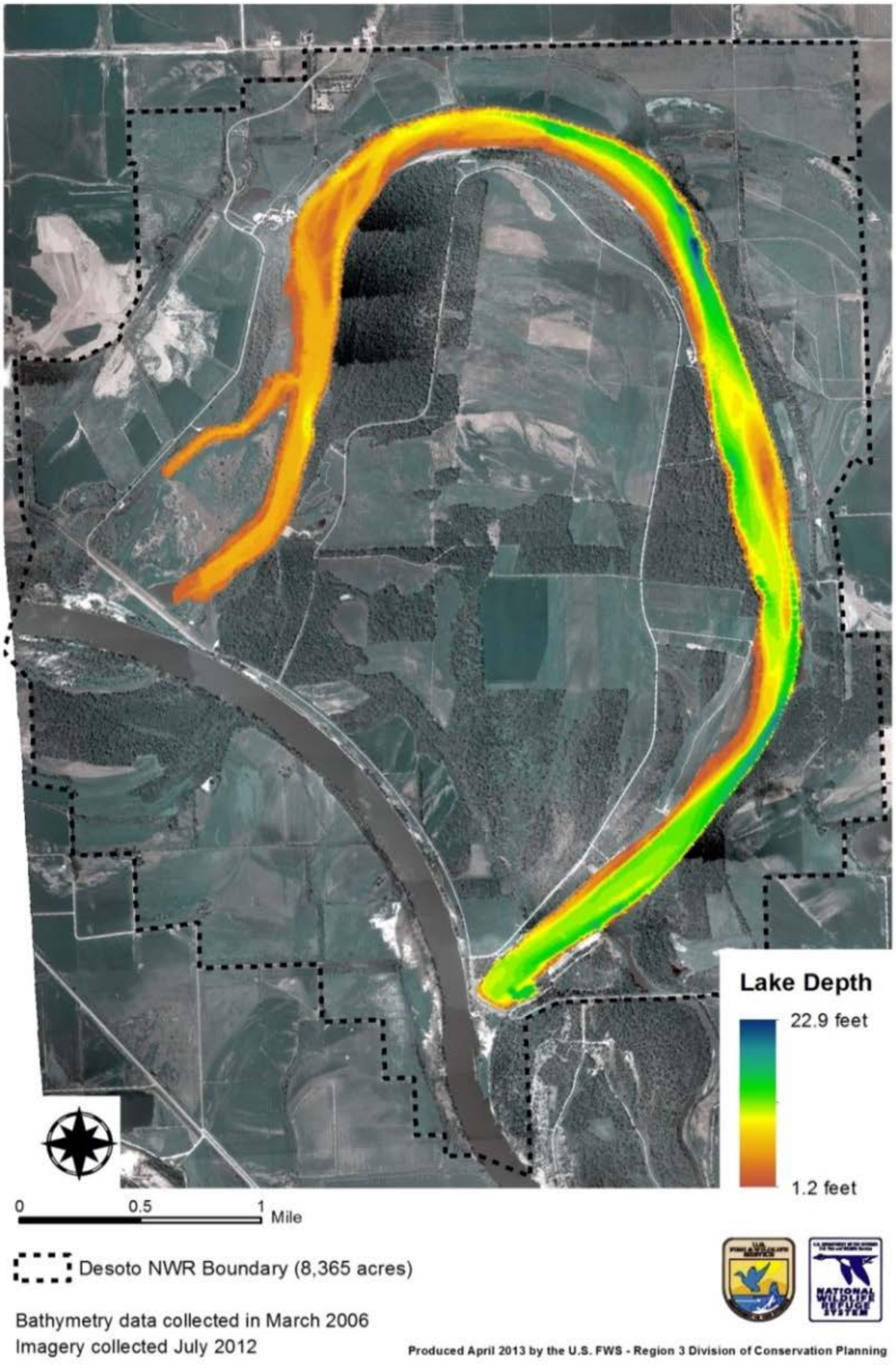


Figure 3-7: DeSoto Lake bathymetry data from 2006

Geology and Surficial Landforms

The bedrock in the area of the refuges are made up of sedimentary deposits from the Late Carboniferous system, Pennsylvanian series, and Missourian stage sedimentary deposits. Typically, layers of shale and limestone predominate in this area, reflecting changes in sea level during the time period aforementioned.

The ancestral channel of the Missouri River is believed to have been displaced by the continental glaciations of the Pleistocene. Prior to glacial intrusion much of the upper Missouri River basin (northward of the Bad River's present confluence with the Missouri at Pierre, South Dakota) drained northeastward into Hudson Bay. As the pre-Illionian glaciers advanced, flows on the Missouri River were forced southeast, and the river began to entrench a new channel along the glacial terminus. Much of the glacial terminus ran near to the historic channel of the Kansas River where it transected much of the present day State of Missouri. As the Missouri River was forced south by the glacial terminus it eventually coalesced with the Kansas River channel, much of which was carved through Pennsylvanian, Mississippian, and Ordovician shale, limestone, and dolomite (Miller 1964; Spooner 2001).

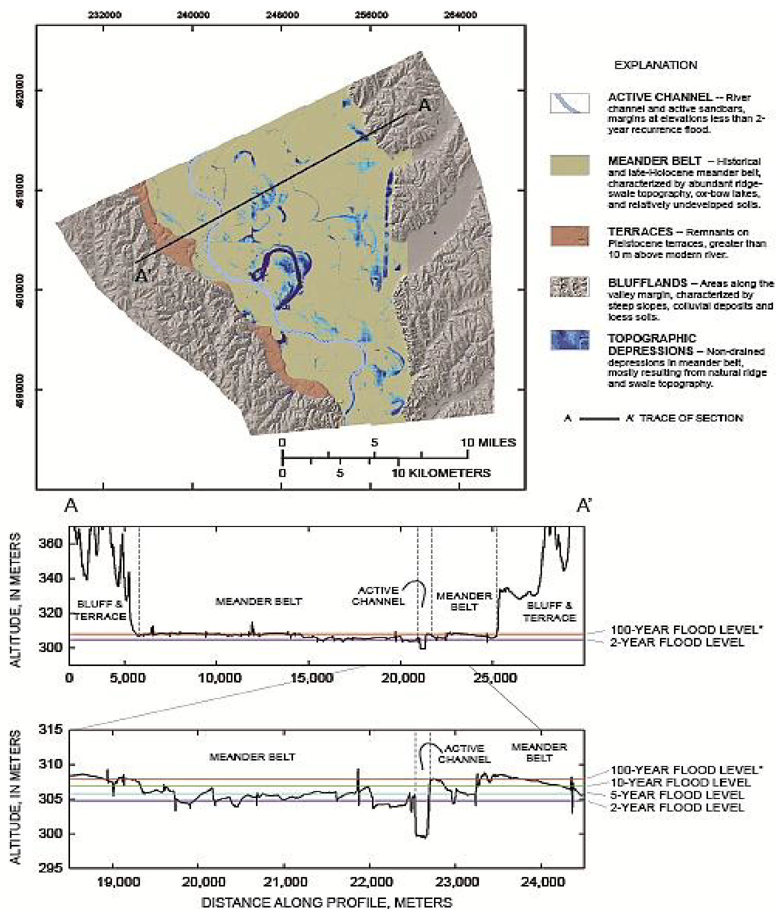


Figure 3-8: Conceptual classification of the lower Missouri River valley-bottom surficial landform and flood hydrology at DeSoto and Boyer Chute NWR (RM 630–655). From Jacobson et al. 2007

Subsequent glacial melting resulted in large amounts of water, which eroded the Missouri River valley and is visible today. Since the end of significant glaciation, surficial landforms are a function of the accumulation of Pleistocene glacial outwash deposits, channel migration, and man-made alterations to its physical form (figure 3-8).

Soils

The refuges lie within the former meander belt of the Missouri River floodplain, an area characterized as a wide, flat valley floor. Historically, the river transported and deposited large sediment loads across the entire area. Some tributary streams in the area also carry large sediment loads, especially those sourced from the highly erodible loess mantled hills. Therefore, the soils found on the refuges and surrounding lands were formed from alluvium deposited by the Missouri River and its tributaries as a function of annual flood cycles and meander migration.

The soils on both refuges are generally low-to-moderate in organic matter and are calcareous (limestone) ranging from neutral to moderate alkalinity. Available phosphorus is generally low, while available potassium is generally high. Permeability ranges from rapid to slow, depending on site-specific alluvium deposition history. Sand, loam, and clay layers vary over short distances; in some areas clays and loams form the upper layer of the soil and are underlain by fine sand and sandy loams. Other areas on the refuges contain soils consisting entirely of clay or entirely of sand. Still other areas have sandy loams over clay or clay loams.

DeSoto and Boyer Chute NWR share the same predominant soil types, which are shown in figures 3-9 and 3-10. The most widespread soil types on both refuges are Haynie silt loam, Onawa silty clay (and silty clay loam) and Albaton silty clay. Haynie silt loam is derived from coarse-silty alluvium and considered well drained with water tables greater than 80 inches below land surface. Onawa silty clay and silty clay loam are also widespread with a parent material of clayey alluvium over loamy alluvium and considered to be somewhat poorly drained with water tables between 18 and 36 inches below land surface. The Albaton silty clay has a parent material of clayey alluvium, is poorly drained, and has water table depths less than 18 inches below the land surface. The Haynie soil type is considered prime farmland along with the Onawa, if drained, but the Albaton is considered undesirable farmland. There is a wide variety of other soils types across both refuges, but they appear sporadically and constitute only a small portion of soils found on the refuges. The Natural Resource Conservation Service (NRCS) has classified most soils on the refuges as “occasionally flooded” (United States Department of Agriculture [USDA] NRCS web soil survey).

The drainage class associated with the soils is illustrated in figure 3-11, which shows a variety of drainage potentials. It should be noted that many of the poorly drained areas may be underlain by well drained sandy layers at depth, which will affect the ability of wetlands to impound water.

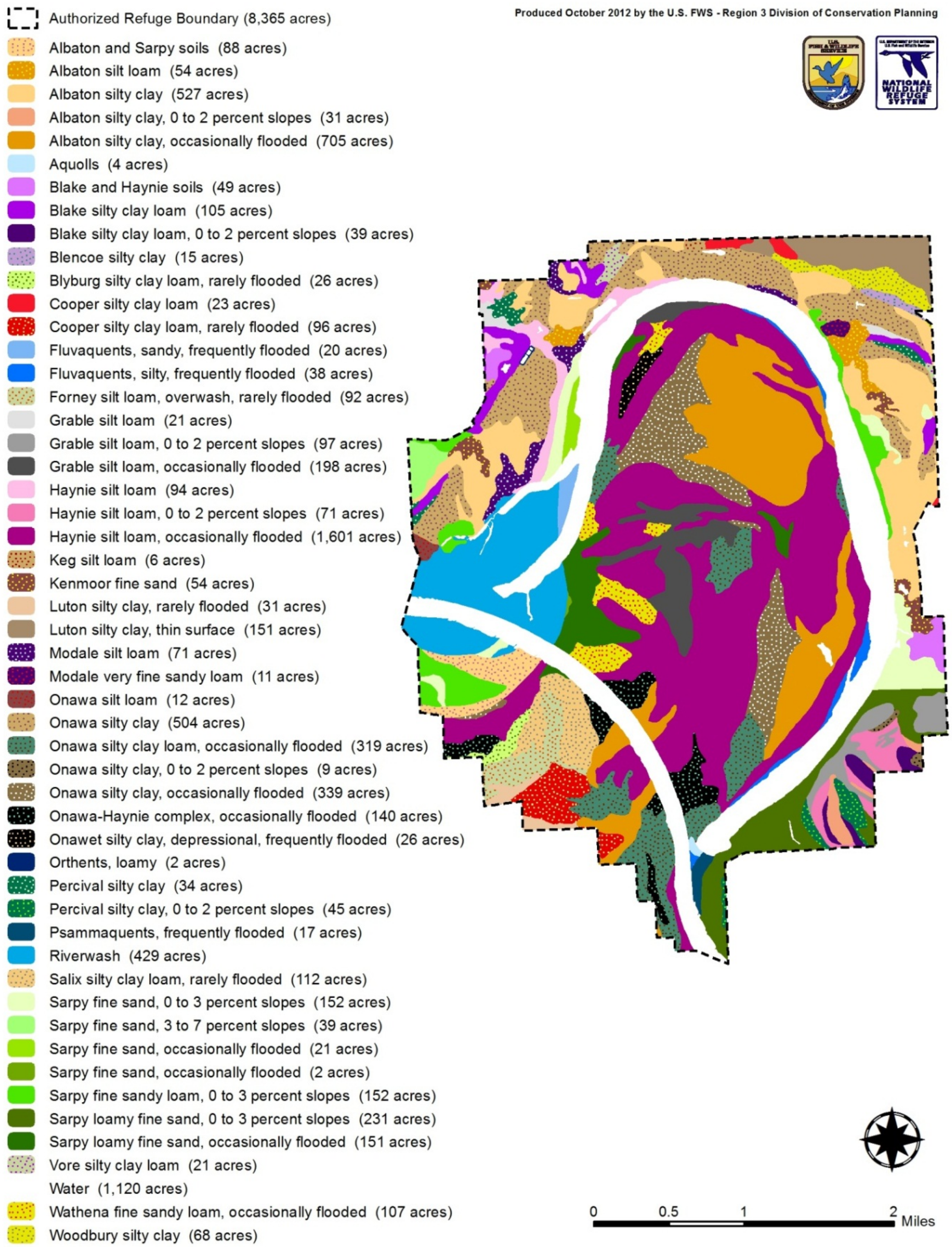


Figure 3-9: Soil types at DeSoto NWR from USFWS 2013

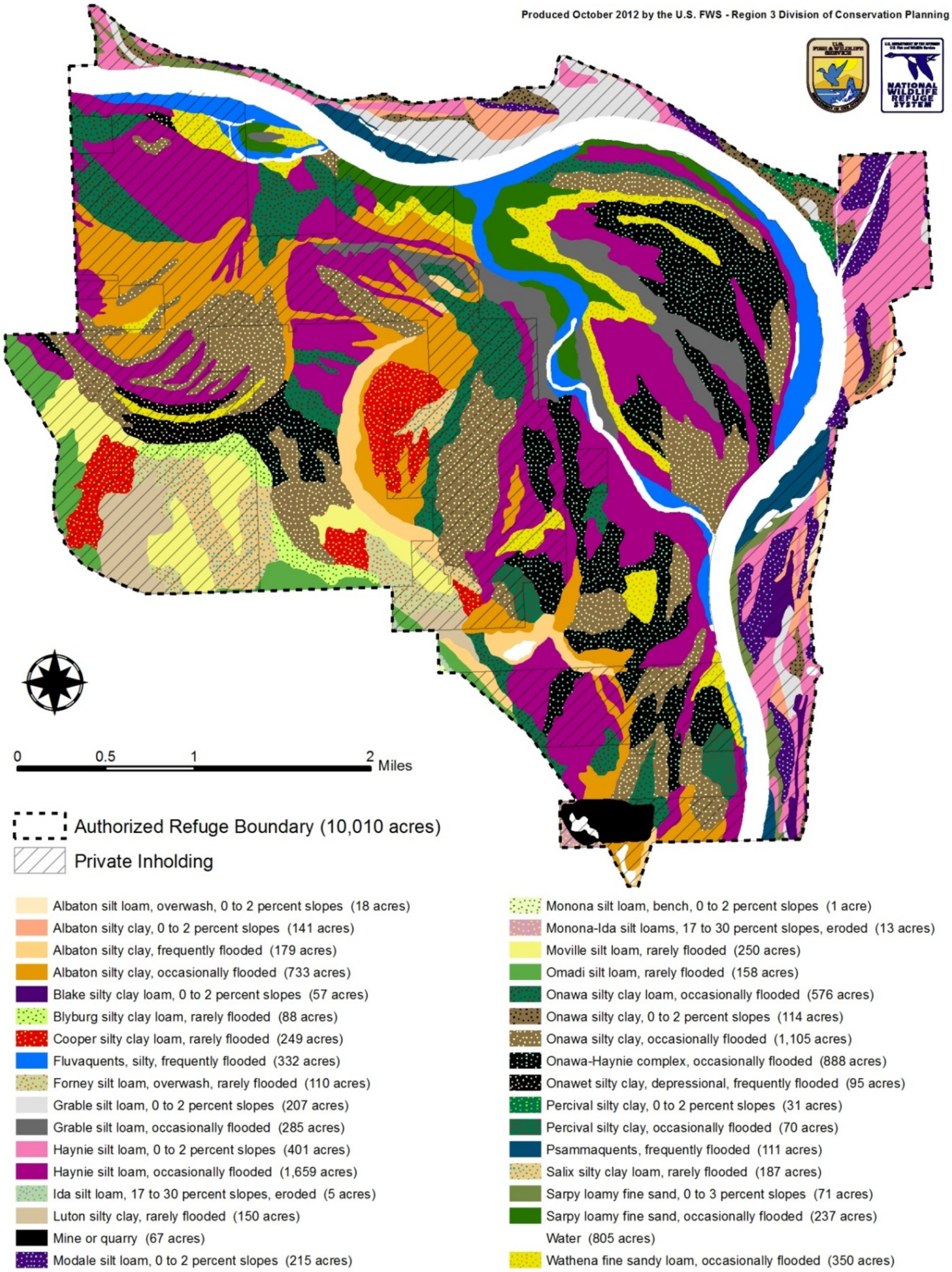


Figure 3-10: Soil types at Boyer Chute NWR from USFWS 2013

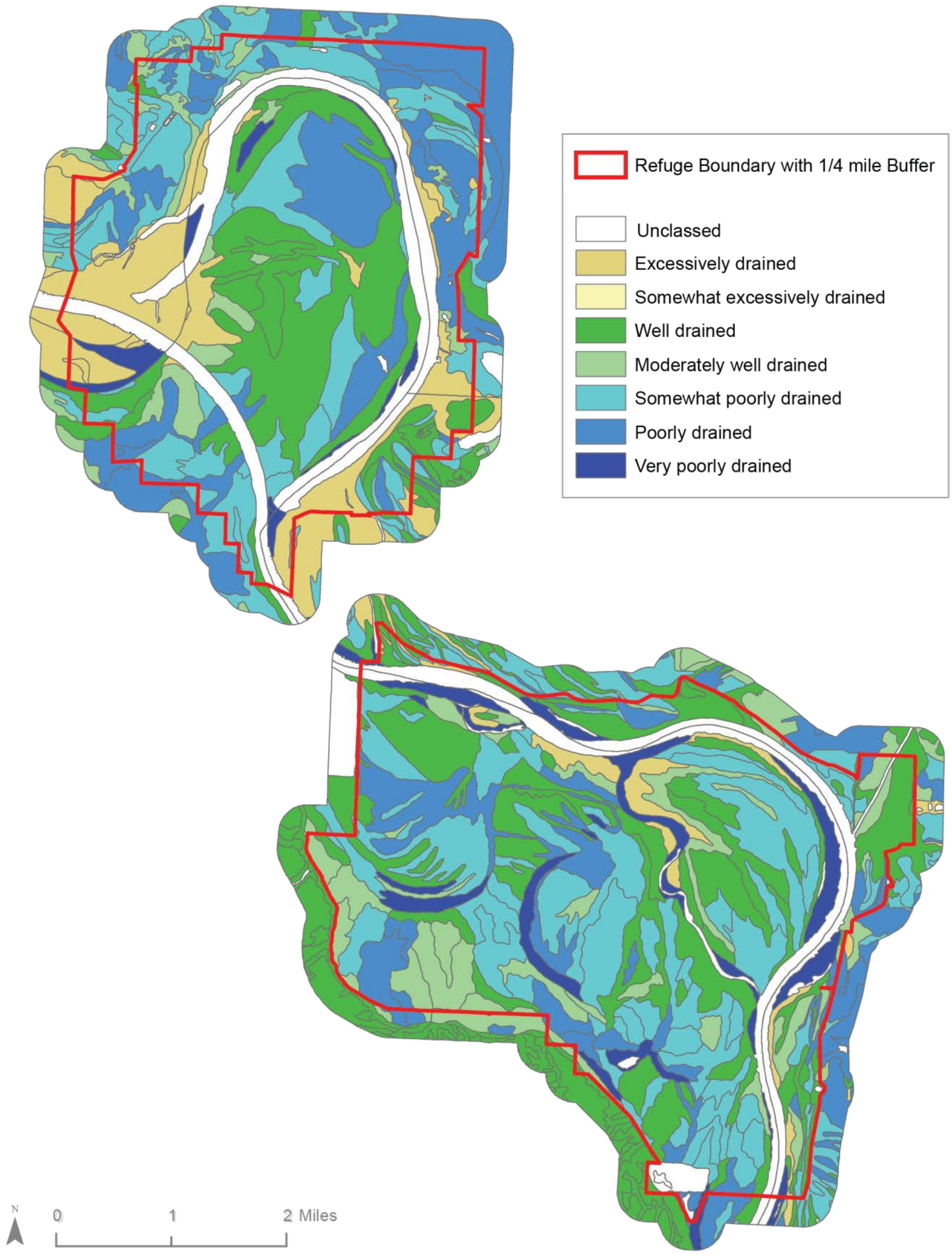


Figure 3-11: Soil drainage class for DeSoto NWR and Boyer Chute NWR

Climate Trends

The WRIA provides a preliminary broad-based analysis of trends and patterns in precipitation and temperature. Climate is defined here as the typical precipitation and temperature conditions for a given location over years or decades. These types of trends and patterns will affect groundwater levels and river runoff and consequently flooding regularity and extent.
There is a variety of methods to evaluate long-term climate trends at refuges, and there are a number of models, scenarios ,and publications that address the current and anticipated trends in this part of the Midwest (e.g., Hayhoe et al. 2007, Union of Concerned Scientists [UCS] 2009, National Oceanic and Atmospheric Administration [NOAA] 2013).

Executive Order 13653 (http://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change?utm_source=Climate+Update+Draft+December&utm_campaign=1st+Climate+Update&utm_medium=email), signed on November 1, 2013, calls for “strengthened resilience to climate change impacts.” Agencies are instructed to prepare for climate change effects that will continue to be felt—by revising policies and programs appropriately, and specifically to identify alterations to be made to land and water-related regulations and programs. Executive Order 13653 directs agencies to encourage the function of natural storm buffers, such as wetlands, and to provide relevant information about climate change to the public so decisions can be made with careful consideration for future impacts. Additionally, agencies need to develop and implement procedures for the identification and management of the most serious threats.

Climate change vulnerability and adaptability are addressed in the CCP for the two refuges:

> *“A climate change study by Magness et al. (2011) on the NWRS gave DeSoto and Boyer Chute Refuges a low exposure rating estimating a 0.011 ºC (DeSoto NWR) and 0.0019 ºC (Boyer Chute NWR) rise in temperature per year based on historic rates of change between 1950 and 2006. The paper also indicated that DeSoto and Boyer Chute Refuges have a low sensitivity to climate change because they are not near the edges of the Temperate Grassland, Savanna, and Shrubland biome (Olson et al. 2001) and contain little critical habitat for threatened and endangered species. They also are considered to have a low adaptive capacity, because they contain little elevation change, a small latitude range, have very little of their watersheds permanently protected, and have a high watershed road density. Based on these conditions, the Refuges’ resilience and vulnerability to climate change were considered moderate.” (USFWS 2013)*

Based on the limitations for adaptation identified in the CCP, development control within the watershed and expanded or improved watershed protection may be the most effective avenues for DSBCNWR to strengthen resilience to impending climate change impacts.

In January 2011, the report *Climate Change Impacts on Iowa*, was released by the Iowa Climate Change Impacts Committee (ICCIC 2011). The report highlights the effects of climate change on Iowa’s economy, health, and natural and agricultural systems and provides recommendations. Iowa is already experiencing higher temperatures, higher humidity levels, and increased precipitation frequency and intensity—particularly in eastern Iowa (ICCIC 2011; NOAA 2013). So far, several reports indicate that the Midwest has already been affected by climate change. According to the Intergovernmental Panel on Climate Change (IPCC) Report

Summary for USFWS (http://www.fws.gov/home/climatechange/pdf/IPCC-Highlights-Full-Version-for-FWS.pdf?utm_source=Climate+Update+Draft+December&utm_campaign=1st+Climate+Update&utm_medium=email) (Johnson et al. 2013), the general increase in intensity and frequency of precipitation across the country has likely resulted in frequent flooding and floods of higher magnitude in particular areas. The Midwest specifically has experienced increases in annual precipitation and runoff and is expected to become wetter overall, with more intense flooding.

Climate models (phase 3 of the Coupled Model Intercomparison Project [CMIP3] and North American Regional Climate Change Assessment Program [NARCCAP]) discussed in NOAA 2013 for the Midwest predict that seasonal increases in temperature could be greatest in the summer and winter, and a longer freeze-free period may be experienced over the region but in differing lengths depending on location. The models predict a statistically significant increase in temperatures for the Midwest by 2055 as well, and annual temperature increases could be the greatest across the central portion, with winter and summer likely exhibiting the largest increases. The report stresses that there is extreme uncertainty in future precipitation predictions. According to the models, an increase in annual precipitation may be observed in the far northern portion of the Midwest, but a decrease could be experienced in the Southwest; and the whole region should experience a greater number of days with precipitation over an inch.

If DSBCNWR experiences milder winters in the future, wetland management will need to adapt in order to sustain quality wintering habitat for waterfowl. There could be additional climate-related implications for Refuge fisheries. For example, if the region experience increased runoff rates, a more dynamic river hydrograph could benefit riverine fish such as pallid sturgeon.

Weather information was collected from a station that fulfills the period of record and data accuracy requirements for the U.S. Historical Climatology Network (USHCN; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which fulfill standards in quality and continuity of data collection. Information was collected from a station located at Logan, Iowa (NOAA station ID: USH00134894), approximately 12 miles to the northeast of DeSoto NWR. The typical historical climate patterns and predicted future trends researched for the WRIA were:

1. The USHCN weather station (1950–2012) showed a mean annual precipitation of 26.5 inches, with the highest rainfall typically in May (figure 3-12). Precipitation was usually 3–4 inches per month, from March until October. Precipitation frequency and intensity have increased from past conditions, with a greater amount of accumulated precipitation from the 10 wettest days of the year and an increase in the number of storms in a 5-year period. This rising trend in precipitation has been statistically significant and is most dramatic in the summer, spring, and fall. Long-term precipitation records show that 1950–1957, 1960–1961 and 1971–1972 were particularly dry. Wetter than normal years included: 1970, 1980–1985, 1993, 2009, and 2011 (figure 3-13).
2. Evaporation from a Class A evaporation pan in Lincoln, NE (~70 miles southwest) averages 60 inches per year, 74 percent of which occurs between May and October. Typically a coefficient of 0.75 is used to relate Class A evaporation pans to lake evaporation, which would suggest that during an average year, approximately 45 inches of water will be lost to evaporation. Typically, sunshine occurs 64 percent of the total possible daylight hours. Average wind speed is 11 mph, and wind direction is

predominantly north by northwest. Strongest winds occur in the spring, with area maximums at 109 mph.

3. Mean monthly temperature is typically highest in July or August and coolest in December–February (figure 3-14). There is evidence of an increase in mean temperature values across the period of record. Winter and spring have shown increased temperatures, although no trend has been reported for summer and fall, and temperature trends are only statistically significant for annual and spring conditions.
4. The North Atlantic Oscillation (NAO) is a climate teleconnection, which is calculated from the atmospheric pressure differential between dipoles located at the Azores and Iceland. The NAO index value is based on data from 1980–2010. In July, the index value of the climate teleconnection is negative correlated to summer precipitation, as a percent of normal (figure 3-15). Very negative index values suggest a future climate scenario of greater precipitation, although other prominent teleconnection patterns may offset this effect.

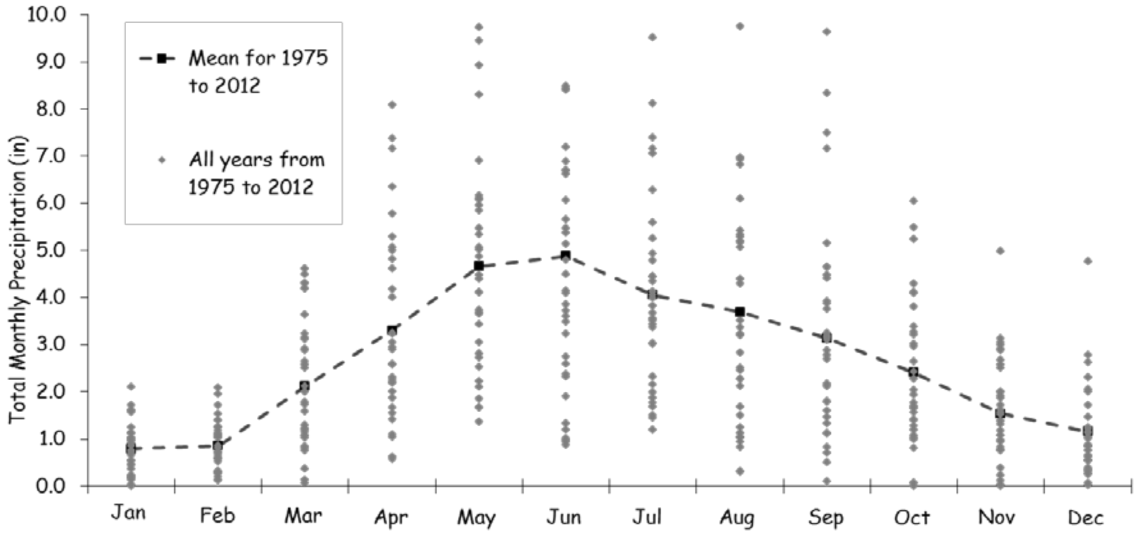


Figure 3-12: Monthly precipitation at Logan, Iowa for 1975–2012

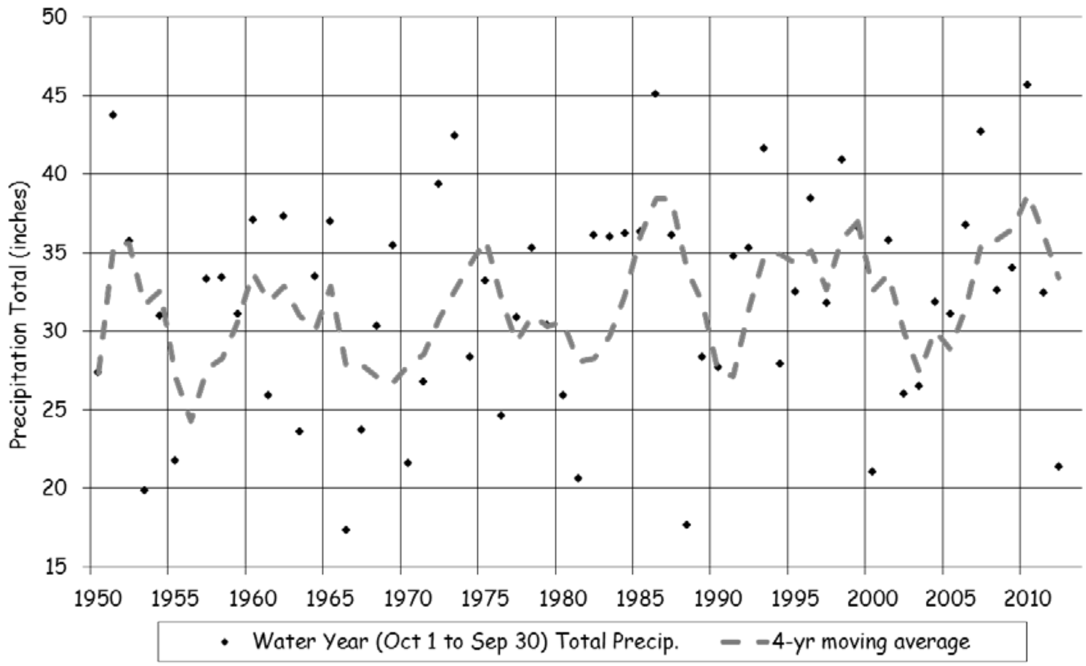


Figure 3-13: Total precipitation for water year at Logan, Iowa for 1950–2012

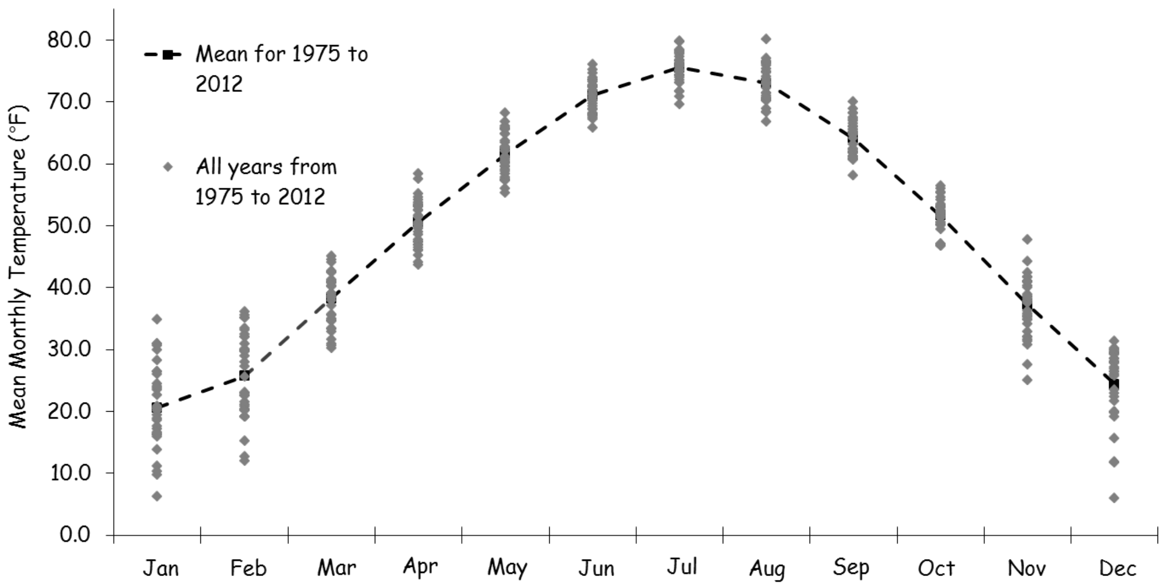


Figure 3-14: Average monthly temperature at Logan, Iowa for 1975–2012

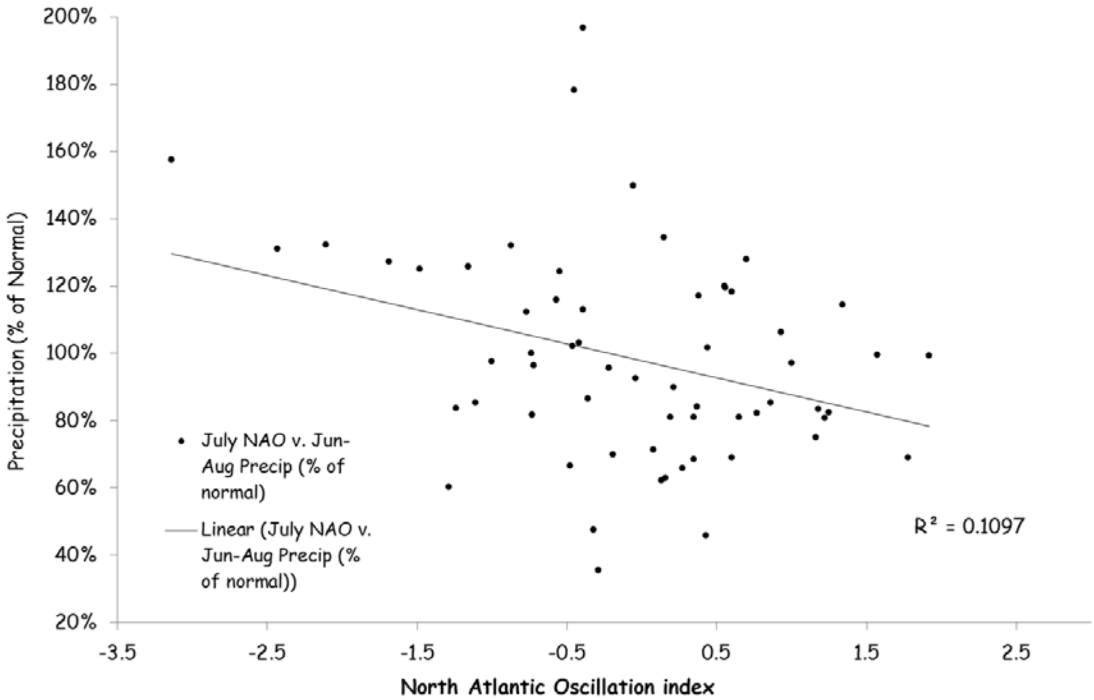


Figure 3-15: Precipitation as a percent of normal (Jun–Aug) versus NAO at Logan, Iowa for 1975–2012

River runoff will be affected by a number of factors versus historical record, as precipitation and temperature patterns change. There has been a roughly 27 percent increase in days with heavy precipitation for this region from 1958–2007 (Groisman et al. 2005), and more precipitation will likely be rain versus snow. These heavy precipitation events lead to flash flooding, increased erosion and do not necessarily recharge groundwater at a proportionally increased rate as soils quickly reach maximum infiltration capacity. However, despite long-term increases in precipitation and runoff in this area over the last century, climate projections do not anticipate continued large increases in runoff (Lettenmaier et al. 2008; Hayhoe et al. 2007).

The expectation is for earlier and higher peak runoff from the larger snow-driven rivers (e.g., Missouri River) in the area and large variability in expected runoff from smaller rivers. There is not currently a pattern of increasing drought, but increasing average summer temperatures may lead to reductions in soil moisture through evaporation and increased evapotranspiration by plants, leading to comparatively less runoff from precipitation events. Currently, it is not unusual for parts of Nebraska and Iowa to experience drought as a result of low precipitation and high temperatures leading to rapid soil moisture depletion. The frequency of these events is likely to increase.

Insight can be gained into the periodicity of annual wet and dry cycles over the long-term using the Palmer Drought Severity Index (PDSI). This index represents moisture conditions based on monthly temperature and precipitation data as well as the soil's water holding capacity at a location (Palmer 1965). A PDSI score ranging from 0.5 to -0.5 is within a normal range of variation. However, the scale extends to scores over 4 or under -4, which indicate wet and dry extremes respectively. The refuges fall into U.S. Climatological Division 25-06, East Central Nebraska, and 13-04, West Central Iowa. The annual PDSI calculations starting in the year 1895 are illustrated in figure 3-16 (NOAA, 2011). In general, dry weather runs in 10-year cycles on the prairie and severe drought in 20-year cycles (Zohrer 2006).

In conclusion, climate scenarios suggest that floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns may change. Rainfall will become more concentrated into heavy events, with longer hotter dry periods intermingled.

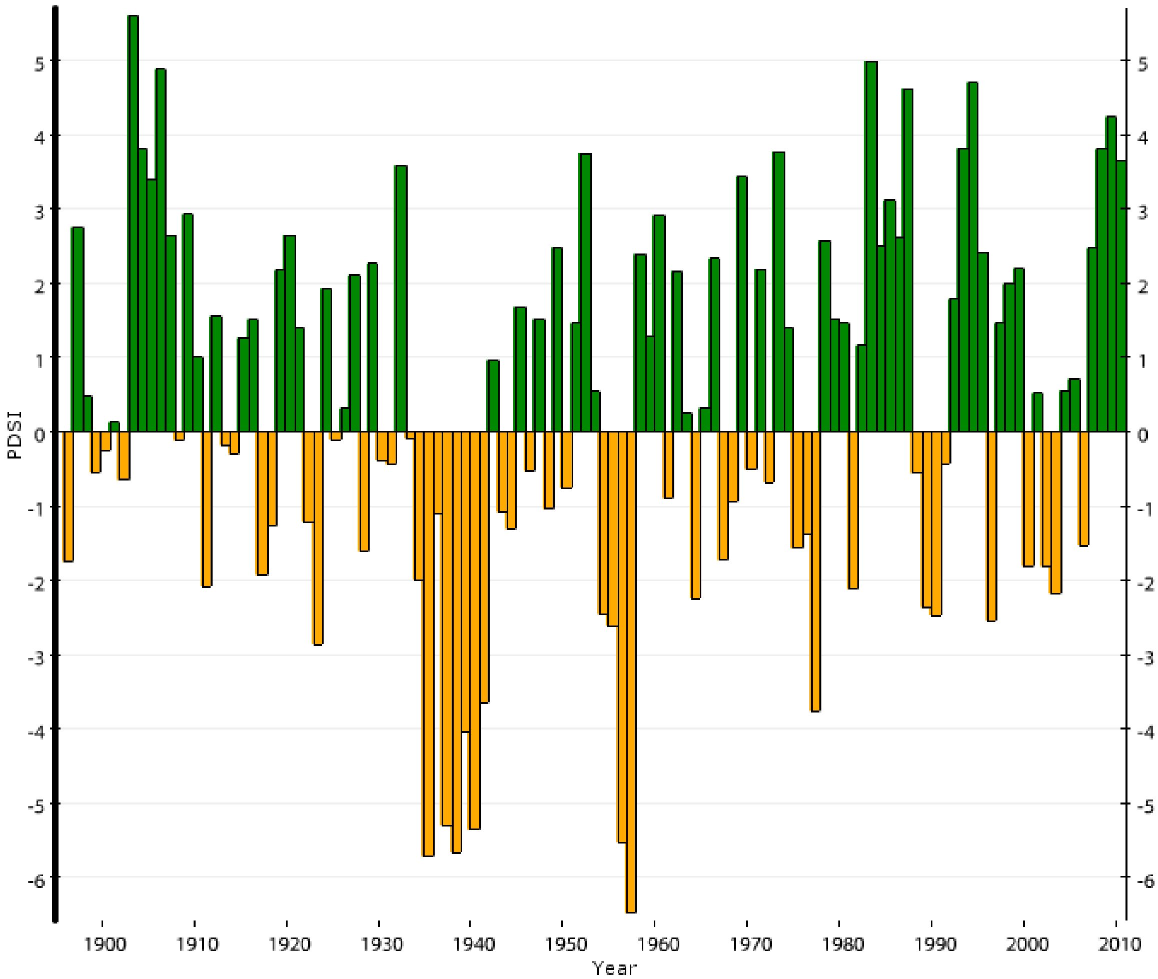


Figure 3-16: Palmer Drought Severity Index (PDSI) (1895–2012) for east central Nebraska and west central Iowa

4. Water Resource Features

Wetlands

The National Wetlands Inventory (NWI) is an extensive, ongoing survey by the U.S. Fish and Wildlife Service, of aquatic habitats across the United States. The NWI is based on interpretation of aerial photographs, not ground surveys, and its criteria differ somewhat from those used in jurisdictional wetlands delineations for permitting by the Corps under Section 404 of the Clean Water Act. The NWI for portions of the refuges in Nebraska was completed using color infrared images (1:58k) from 1982, while those wetlands located on the Iowa side of the refuges were identified using a series of three spring infrared images from 2002.

DeSoto NWR

The NWI (see Appendix A National Wetland Inventory) classified approximately 21 percent of the DeSoto NWR acquired area as wetland, with “lake” being the most prominent type (10 percent of the acquired area, 845 acres). Together, lacustrine and riverine wetlands make up roughly 62 percent (1098 acres) of the total wetland area. Nearly all of the lacustrine units are limnetic, permanently flooded wetlands with unconsolidated bottom substrates and are listed as diked or impounded by man-made barriers. The majority (99 percent, 251 acres) of riverine wetland area is permanently flooded with an unconsolidated bottom, although some (1 percent, 3 acres) is classified as unconsolidated shore and temporarily or seasonally flooded waters. All of the riverine wetlands are indicated to be lower perennial with a slow flow, low bed slope, and a well-established floodplain. The remaining 38 percent (664 acres) of the NWI wetland area is classified as palustrine and is primarily concentrated in the western portion of the refuge surrounding the Missouri River and DeSoto Lake. Most of the palustrine area is dominated with forested (44 percent, 294 acres), emergent (31 percent, 204 acres), or scrub/shrub (19 percent, 129 acres) vegetation, while some is classified as unconsolidated bottom or shore (5 percent, 36 acres). Nearly half (48 percent, 141 acres) of the forested palustrine wetlands are further categorized with a dominance of broad-leaved deciduous trees and shrubs. For the most part, these palustrine wetlands are either temporarily (59 percent, 390 acres) or seasonally (35 percent, 230 acres) flooded, while some areas are semi permanently/permanently flooded (5 percent, 32 acres) or intermittently exposed (2 percent, 11 acres). They are also commonly indicated as diked or impounded (27 percent, 181 acres), and some areas are partially drained/ditched (5 percent, 31 acres) or excavated (2 percent, 10 acres). Acreage of specific wetland units within the refuge are summarized in table 4-1.

Table 4-1: Acreage and water sources of wetland units at DeSoto NWR (USFWS CCP 2013)

Feature Name	Source Water	Acres*
Headquarters Wetlands	Precipitation, pump from well and/or Lake	88
Red Barn Wetlands	Precipitation Pumped from 2 wells or Lake	65
Botos Wetlands	Pumped from one of the Botus well	64
Lone Tree Wetlands	Pumped from 2 wells in northwest and southeast corner of unit	175
Center Island	Pumped from lake and natural run off	220
DeSoto West	Precipitation, historically pumped from river	50
Whitetail	Precipitation and pumped from lake	120
Rail units	Precipitation and Botus well	45
DeSoto Lake**	Precipitation and River	200
Visitor Center	Precipitation and pump from Lake	170
Wood Duck Wetlands	Pumped from DeSoto Lake	98
Total Acres	-	1,295
*Acres are approximate calculations **Total acreage for DeSoto Lake, including non-wetland areas, is roughly 990-992.5		

Refuge wetland water management was summarized in the CCP (USFWS 2013)

> *"Water control structures are used to manage water levels. Additional management actions include pumping water between units, disking wetlands, and prescribed burning. Water is typically pumped into units in the fall to provide stopover habitat for migratory waterfowl.*
>
> *DeSoto NWR's wetlands consist of historic scours, side channels, oxbows, and natural depressions. Several factors have limited the size and extent of wetland habitats on the Refuge in the past, including the following:*
>
> - *Many wetland areas were modified to trap sediment in the past as a part of the Corps' Bank Stabilization and Navigation Project.*
> - *Missouri River channel training structures and greater control of the river's water levels have virtually eliminated the natural overbank flooding that once occurred within the floodplain—along with the natural wetland complexes that were created and replenished by these flood events.*
> - *DeSoto Lake's water levels have been maintained below certain thresholds to avoid drainage issues with upstream landowners…"*

Though in the past wetland restoration activities have been limited to facilitate the agriculture program, this program has been eliminated and the affected wetlands have been restored. Today, DeSoto NWR has an estimated 1,295 acres of managed wetlands in five wetland complex management units, which offer migratory birds a diversity of habitats, including forests, annual emergent vegetation, dense perennial vegetation, mudflats, and open water (USFWS 2013).

DeSoto Lake – From CCP (USFWS 2013)

> *"DeSoto Lake is a large, prominent, and central feature of DeSoto NWR. The surface area of the lake varies seasonally, but average total surface area ranges from 800–900 acres. The water volume has been estimated at approximately 6,390 acre feet. According to a 2006 USGS study, average water levels in the lake range from 986.5 to 989.5 feet above MSL, constituting a difference of 156.5 acres of surface area (Elliot et al. 2006). Multiple drainage ditches extend over 24 linear miles and drain 12,563.46 acres (19.63 square miles) of predominantly agricultural private land in the watershed before entering DeSoto Lake via three primary inputs (Iowa DNR 2012). Water levels in DeSoto Lake are influenced by four major factors related to precipitation in the watershed: runoff from the three aforementioned agricultural drainage ditches (Young's, Rand's, and Brown's Ditches) that release into the lake, Missouri River flows, sheet flow over the land surface, and local groundwater levels…*
>
> *…The three drainage ditches that terminate in DeSoto Lake are a substantial source of suspended sediment. There are pending water quality issues related to turbidity and algae, and the lake is currently listed as a state impaired water by the Iowa DNR under section 303(d) of the Clean Water Act. Watershed farmers are encouraged to put buffer strips of native vegetation along drainage ditches. Water from agricultural ditches is pumped into Refuge wetlands to filter drainage when possible. Limited water quality monitoring is conducted in the lake."*

Boyer Chute NWR

Roughly 10 percent (380 acres) of the Boyer Chute NWR acquired boundary is wetland according to the NWI. Freshwater forested/shrub wetlands are the most prominent, accounting for 5 percent (207 acres) of the acquired area. Most of these wetland units are located along the Missouri River and Boyer Chute flow paths. The riverine wetlands account for nearly 20 percent (76 acres) of the wetland area, have unconsolidated bottom substrates, are lower perennial, and are either intermittently exposed or permanently flooded. The remaining palustrine wetlands (80 percent of wetland area, 305 acres) are typically dominated by scrub/shrub (36 percent, 109 acres), forested (32 percent, 98 acres), or emergent (23 percent, 71 acres) vegetation; while some units are classified with unconsolidated bottom substrates (6 percent, 19 acres) or aquatic beds (2 percent, 7 acres). Most of these units are seasonally flooded (69 percent, 211 acres), but some are flooded semi-permanently (17 percent, 51 acres) or temporarily (14 percent, 42 acres).

Refuge water management was summarized in the CCP (USFWS 2013)

> *"Climatic conditions and rain events largely dictate the water availability within most of Boyer Chute NWR's wetlands. Refuge staff work to maintain productive wetland habitat for waterfowl feeding and resting and for other wildlife by maintaining a healthy balance of open water and emergent vegetation. Periodic soil disturbance is used to stimulate annual forb germination. Water level management and herbicide application are also used to control undesirable emergent and aquatic vegetation such as river bulrush, cattails, and phragmites.*

Boyer Chute NWR is able to manage water levels in 12 wetland units using 16 water control structures. Six of these wetland units (approximately 124 acres) use water-control structures to divert water from Deer Creek into the basins. In non-drought years there is adequate drainage in Deer Creek to supply the needed water to all six wetlands…

…Five additional wetlands encompassing approximately 76 acres also have water control structures to provide management capability but are entirely dependent upon precipitation or Missouri River flooding to supply water…

…There also are a number of wetlands on the Refuge in which climatic conditions largely dictate water availability because a direct water source is unavailable. Boyer Chute NWR has 232 acres of these unmanaged wetlands…

…There is one additional 30-acre wetland area not owned or managed by the Service but located within the authorized boundary, Boyer Bend WMA Wetland. This wetland is owned and managed by the Iowa DNR. The Fort Calhoun Drainage District maintains an easement on Deer and Turkey Creeks, permitting access for maintenance."

The acreage and source waters for these wetlands are summarized in table 4-2.

Table 4-2: Acreage and water sources of wetland units at Boyer Chute NWR (USFWS CCP 2013)

Feature Name	Source Water	GIS Acres**
Bluewing Wetlands*	Missouri River, precipitation, and well pumping	7.5
Boyer Bend Backwater	Missouri River	36.6
Boyer Chute	Missouri River	57.4
Dugout Wetlands	Climate dependent – direct source unavailable	4.2
Horseshoe North (north of water control structure)*	Missouri River and precipitation	15.4
Horseshoe South (unrestored drained basin, currently drained by the Fort Calhoun Drainage District)	Climate dependent – direct source unavailable Precipitation, Mo River and excess flow from mallard wetlands	91.2
Mallard Wetlands East*	Deer Creek diversion	30
Mallard Wetlands West*	Deer Creek diversion	55
Meander Wetlands*	Missouri River and precipitation	5.2
Mud Lake North*	Missouri River and Deer Creek diversion	15.2
Mud Lake South*	Deer Creek diversion	19.3
Nathan's Lake East*	Deer Creek diversion	27.9
Nathan's Lake West*	Deer Creek diversion	16.5
Pintail Wetlands*	Climate dependent – direct source unavailable	7.1
Rail Wetlands*	Missouri River and precipitation	21.2
Skink Wetlands	Climate dependent – direct source unavailable	21.9
West Dike North	Climate dependent – direct source unavailable	3.7
West Dike South	Climate dependent – direct source unavailable	1.1
Yellowlegs Wetlands	Missouri River and precipitation	26.8
TOTAL ACRES	---	372
*Denotes management capability **All GIS acreages are approximate calculations of areal extent based on 2010 aerial imagery		

NHD Flow Lines (Streams, Creeks, and Ditches)

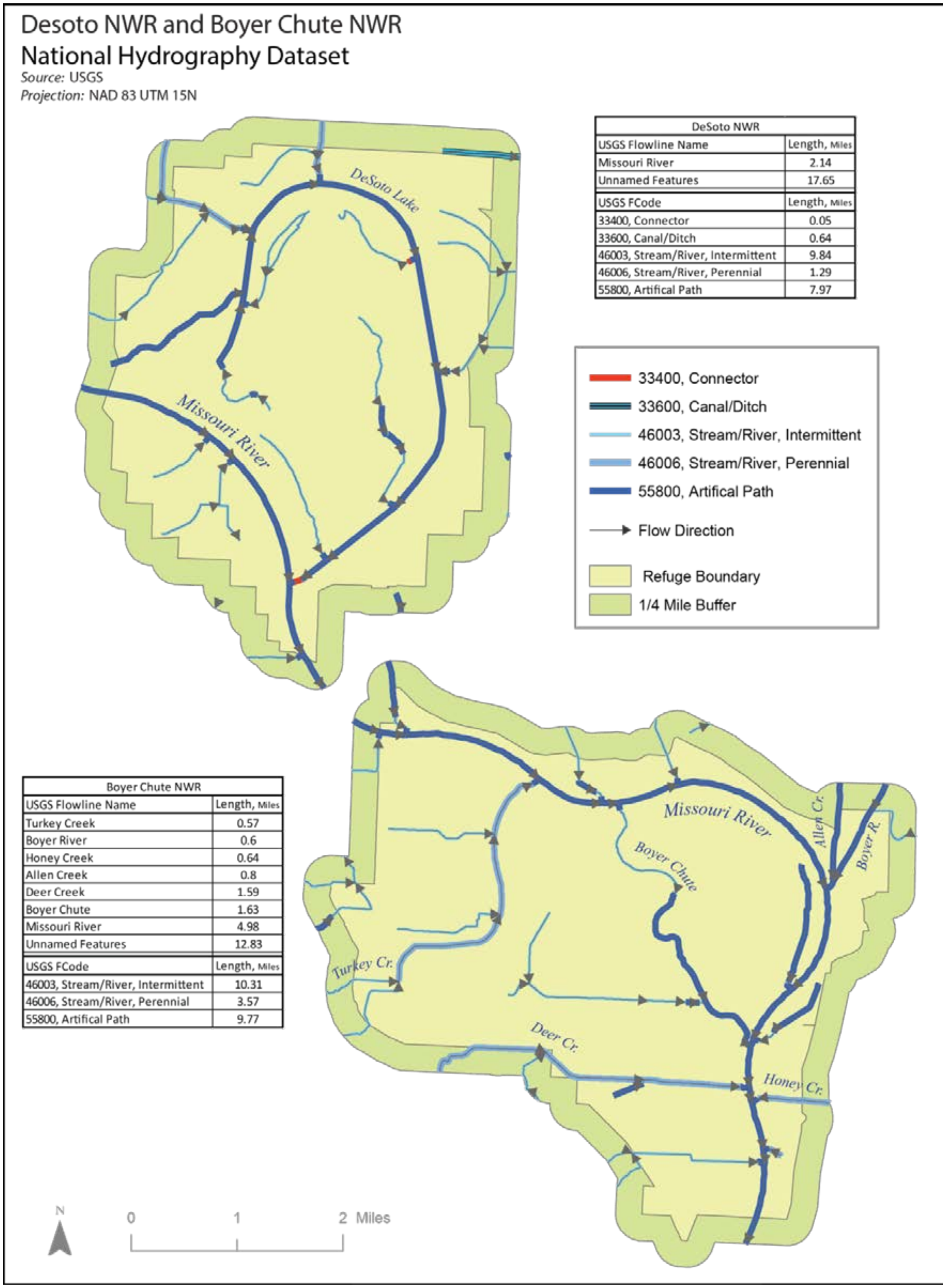
All of the artificial and perennial features and most of the intermittent streams and rivers identified throughout DSBCNWR by the National Hydrography Dataset (NHD) (figure 4-1) are easily detectable on aerial images. Some slight discrepancies may exist in the western portion of DeSoto Lake, where the water extends closer to the bank of the Missouri River and the intermittent flow path is difficult to distinguish.

DeSoto NWR

According to the NHD, 2.14 miles of the Missouri River flow line is within the DeSoto NWR acquisition boundary (and 0.25-mile buffer). In total, there are approximately 0.64 miles of canals and ditches and 7.97 miles of artificial flow paths within the boundary and buffer zone. Roughly 9.84 miles of flow within this extent are intermittent, while 1.29 miles are identified as perennial. Unnamed features account for 17.65 miles of flow within the assessment area.

Boyer Chute NWR

A 4.98-mile stretch of the Missouri River meanders through Boyer Chute NWR (and 0.25-mile buffer). Within this boundary, it is joined by a portion (0.57 miles) of the Turkey Creek flow line. Farther downstream, Boyer Chute provides a 1.63 mile path, which separates flow from a meander in the Missouri River. A portion of Allen Creek (0.8 miles) and Boyer River (0.6 miles) join into this meander from the north. Downstream of the Missouri River and Boyer Chute confluence, 1.59 miles of Deer Creek flow in from the west while 0.64 miles of Honey Creek enter from the east of the Missouri River. In total, approximately 10.31 miles of intermittent streams and rivers, 3.57 miles of perennial streams and rivers, and 9.77 miles of artificial flow paths are identified by the NHD within the acquisition boundary and buffer zone.



DeSoto NWR	
USGS Flowline Name	Length, Miles
Missouri River	2.14
Unnamed Features	17.65
USGS FCode	Length, Miles
33400, Connector	0.05
33600, Canal/Ditch	0.64
46003, Stream/River, Intermittent	9.84
46006, Stream/River, Perennial	1.29
55800, Artifical Path	7.97

Boyer Chute NWR	
USGS Flowline Name	Length, Miles
Turkey Creek	0.57
Boyer River	0.6
Honey Creek	0.64
Allen Creek	0.8
Deer Creek	1.59
Boyer Chute	1.63
Missouri River	4.98
Unnamed Features	12.83
USGS FCode	Length, Miles
46003, Stream/River, Intermittent	10.31
46006, Stream/River, Perennial	3.57
55800, Artifical Path	9.77

Figure 4-1: NHD and flow directions at DeSoto NWR and Boyer Chute NWR

Infrastructure Water Control Structures

20 water control structures (WCSs) are identified at DeSoto NWR, and 14 WCSs are identified at Boyer Chute NWR (Table 4-3; Figures 4-2 and 4-3). A significant portion of these structures use boards or stop logs to manipulate water levels in wetlands and moist soil units. These structures currently have survey quality GPS coordinates, elevation information from structure cross bars and in many cases staff gages.
In addition to these structures levees, refuge roads, and ditches are controlling and directing water, limiting sheet flow or fragmenting units.

Table 4-3: Water Control Structures at DSBCNWR

DeSoto WCS	Type	Boyer Chute WCS	Type
Botos	24” Inlet PVC	Blue wing	18” Inlet PVC
	16” Inlet PVC	Horseshoe complex	18” Inline PVC
	16” PVC	Horseshoe ditch	36” Metal Inline
Center Island	24” Inlet PVC	Mallard	16” Screw gate
	24” Screw gate	Nathans lake east	3 Way metal structure
DeSoto West	Metal half round		36” Metal Inline
	Metal half round	Nathans lake west	18” Inline PVC
	24” Flap gate		18” Inlet PVC
Headquarters	24” Inlet PVC		18” Inlet PVC
	18” Inlet PVC	Rail	24” Inline PVC
	18” Inlet PVC	Turkey Creek	24” Metal half round
	18” Inlet PVC	West lake	18” Inline PVC
Lone tree	Metal half round		10” Inline PVC
Rail Unit	18” Inlet PVC	Yellowlegs	18” Inline PVC
Red Barn	Metal half round		
Visitor Center	24” Inlet PVC		
White Tail	24” Inline PVC		
Willow Pond	Metal half round		
Wood Duck	24” Inlet PVC		
	18” Inlet PVC		

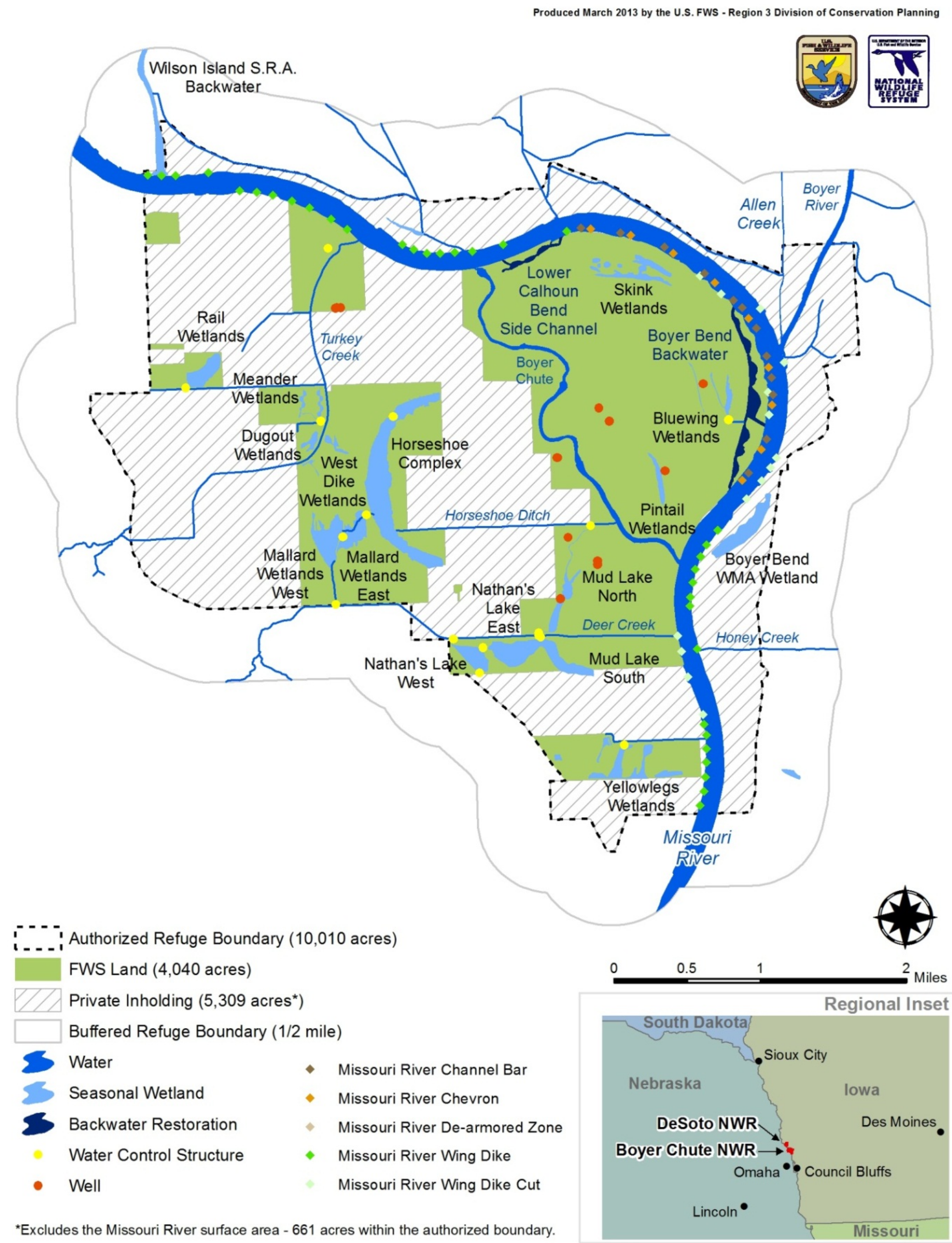


Figure 4-2: Water features and water control structures at Boyer Chute NWR

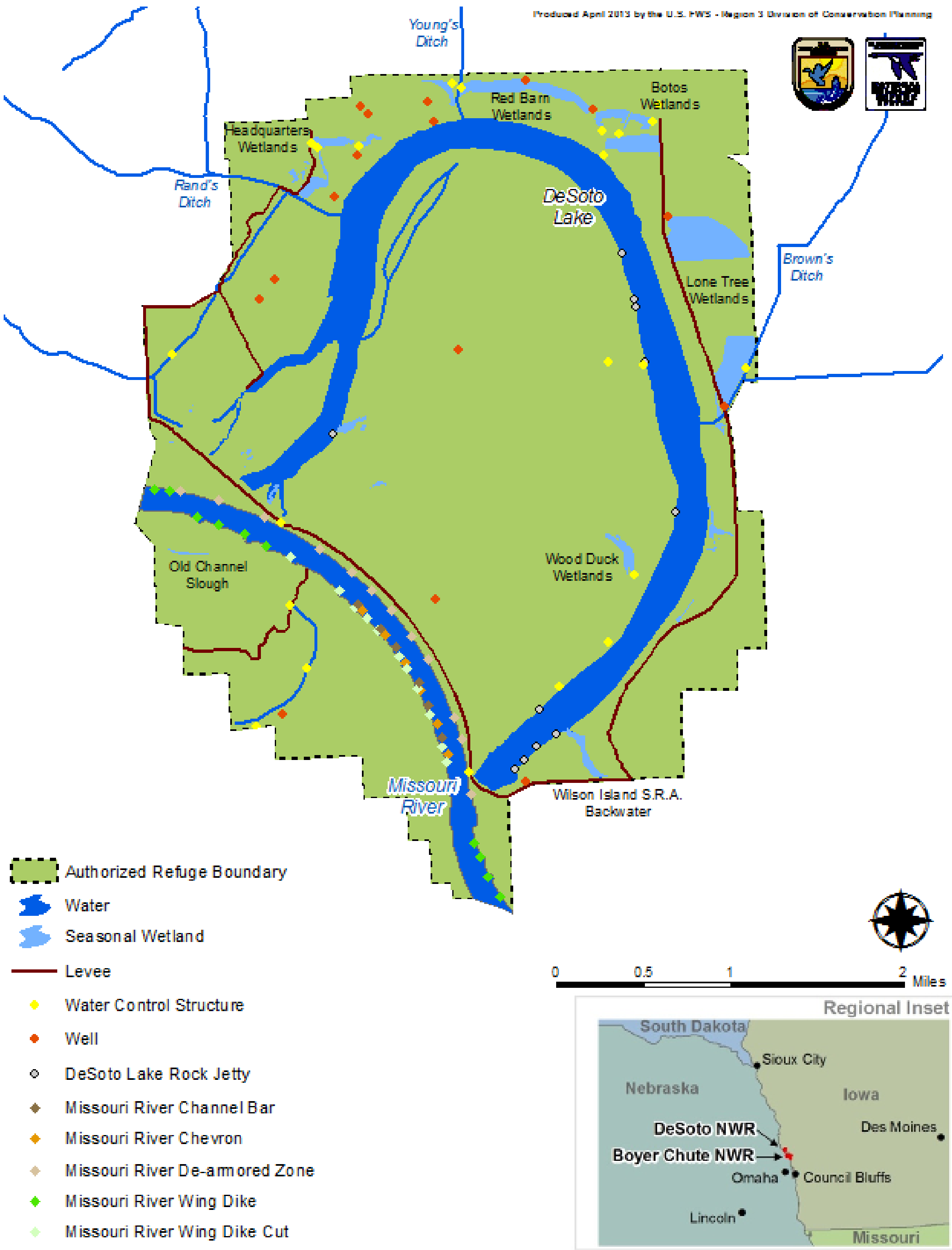


Figure 4-3: Water features and water control structures at DeSoto NWR

5. Water Resource Monitoring

The WRIA identifies historical and ongoing water resource-related monitoring on or near the refuges. Water resource monitoring can be divided broadly into surface or groundwater quality and quantity monitoring.

Water quantity is typically a stage and/or discharge measurement in a stream or aquifer. For example, staff gages have been installed at multiple locations on the refuges to monitor water levels in the units. Quantity information was briefly evaluated for applicability, period of record, and trends.

Water quality can include laboratory chemical analysis, deployed sensors, or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, a measure of stream purpose attainment by state natural resources management organizations.

Water Monitoring Stations and Sampling Sites

A list of sites that are relevant but not necessarily directly applicable to the resources of concern or that are currently inactive was created. This can be found with the table of applicable sites in Appendix B Water Monitoring Sites (STORET). Data was collected from the USEPA STORET (STOrage and RETrieval) database, which houses monitoring data collected by the states under the Clean Water Act. Surface water stations were considered applicable if they were located within the HUCs of interest and/or drainage areas adjacent to refuge property.

Groundwater monitoring has been conducted in the general area of DeSoto NWR and Boyer Chute NWR by the Iowa DNR and the USGS. Some data can be found in the 1992 USGS report T*he Ground-Water-Level Monitoring Network in Iowa* (Lambert 1992).

Water quality sampling was funded by the USFWS Environmental Contaminants program and conducted around the DeSoto NWR from 1989–1990 by the Iowa State University Extension Office and the Leopold Center. Analysis of samples focused primarily on pesticides (see the Leopold Center report [http://www.leopold.iastate.edu/sites/default/files/grants/1988-04.pdf]).

Sampling for river water quality and other ecological parameters in the Missouri River also occurred as part of the Environmental Monitoring and Assessment Program for the Great River Ecosystems (http://cpcb.ku.edu/research/great-rivers-study/). Seven of these monitoring locations were located within the refuges' zone of hydrologic influence.

Surface Water Quantity

Hydro-Climatic Data Network

In our assessment of the patterns in surface water quantity, we compared several of the sites qualitatively to a reference hydrograph obtained from the Hydro-Climatic Data Network (HCDN) site. The HCDN is a network of stream gages located within relatively undisturbed watersheds with minimal anthropogenic influences, which are appropriate for evaluating trends in hydrology and climate that are affecting flow conditions (Slack et al. 1992). This network attempts to provide hydrologic information without the confounding factors of direct water manipulation and land use changes. Temporal trends in data at sites relevant to DSBCNWR were evaluated with consideration to trends identified at the relevant HCDN site.

The Little Sioux River at Correctionville, Iowa (see USGS 06606600 [http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=06606600&agency_cd=USGS]) is the closest HCDN site that relates to DSBCNWR's water resources. The site shows a recent increase in average annual discharge and increase in variability of the data, from values recorded since the early 1900s (figure 5-1). Simple linear regression of the longest complete period of record (1936-2013) reveals a statistically significant increase in average annual discharge, although there is no significant trend in data from more recent years (1984–2013). This information suggests that more water is being transported in the Little Sioux over the past 30 years than historically has been. Assuming this gage represents a relatively natural flow regime, these trends may primarily be due to changes in hydrology and climate or in part by land use change, rather than more-direct anthropogenic influences such as flow regulation. Data from another relevant gage in the area, (see USGS 06609500 [http://waterdata.usgs.gov/nwis/nwisman/?site_no=06609500&agency_cd=USGS]) at Logan, Iowa, reveals the same long-term change. Thus, any identified trends in gages located in downstream waters more-relevant to DSBCNWR could be functions of multiple anthropogenic factors as well as hydro-climate changes in the area.

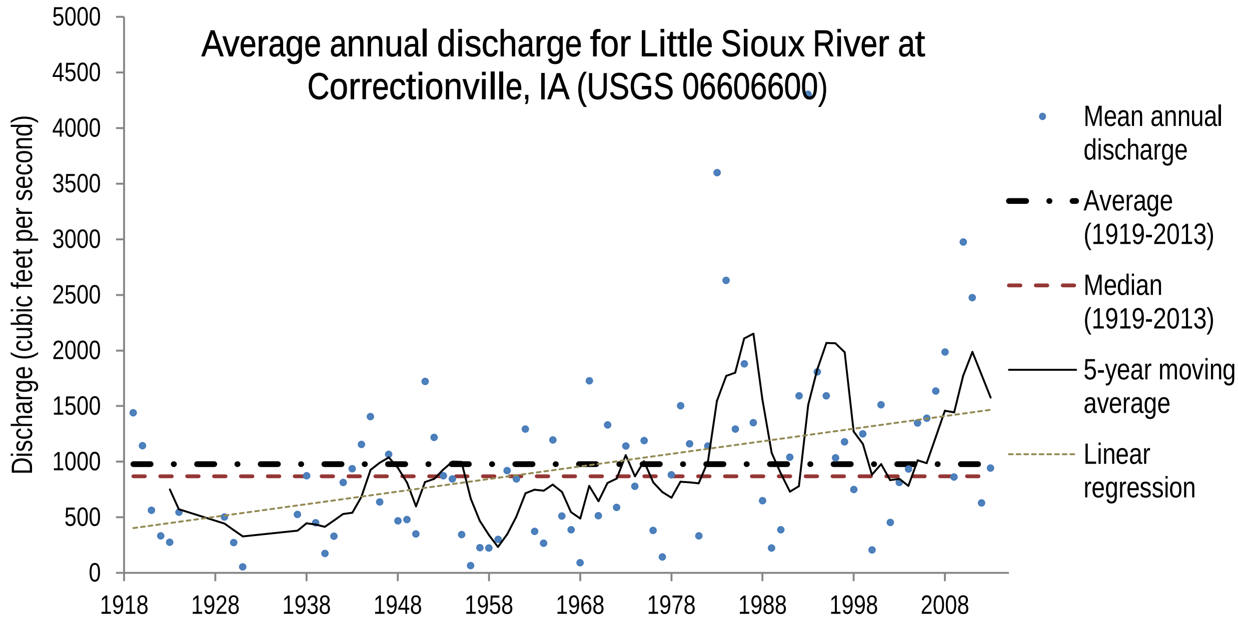


Figure 5-1: Annual average discharge for Little Sioux River at Correctionville, Iowa (USGS 06606600) (1919–2013)

Missouri River Models

The most recent modeling of Missouri River discharge and elevation is based on streamflow data collected on the Missouri River after regulation of the river was initiated up to 2003, and can be interpolated by Missouri River mile from a 2003 report published by The USACE-Omaha district (USACE 2003) (table 5-1, figure 5-2). These values were developed using an unsteady flow hydrologic model in combination with the Bulletin 17B method (Interagency Advisory Committee on Water Data [IACWD] 1982) to derive flood elevations for a 2- to 200-year event. The return interval (often referred to as “flood frequency”) is a statistical estimate of the time between specific water discharges. This is the likelihood of reaching a particular maximum discharge for a given location on the river. For example, the 5-year return interval has a 20 percent likelihood of occurring in a given year and a 100-year return interval has a 1 percent chance of occurring in a given year. The limitations of the methods in Bulletin 17B, Federal Guidelines for Determining Flood Flow Frequency (IACWD 1982), are discussed within the most recent modeling effort. An updated flow frequency modeling effort is currently being conducted by the USACE to recalculate the hydrology and hydraulics of the Missouri River.

Table 5-1: Interpolation of return intervals for Missouri River flows and water surface elevation for river miles adjacent to Boyer Chute and DeSoto NWRs; discharge in cubic feet per second and elevation in feet, Mean Sea Level (NGVD 1929)

Return Interval	Discharge (cfs) Mile 632	Elevation (NGVD 1929) Mile 632	Discharge (cfs) Mile 640	Elevation (NGVD 1929) Mile 640
2	63,700	984.2	62,000	991.4
5	84,700	987.5	82,600	994.2
10	122,100	991.7	117,000	996.9
25	131,400	992.5	127,000	997.5
50	146,800	993.6	142,900	998.4
100	173,400	995.5	168,700	999.5
200	202,900	997.3	197,200	1000.9

Peak elevation and discharge for the Missouri River (Mile 632 and 640) at the upstream and downstream ends of Boyer Chute NWR.

Return Interval	Discharge (cfs) Mile 641	Elevation (NGVD 1929) Mile 641	Discharge (cfs) Mile 645	Elevation (NGVD 1929) Mile 645
2	62,000	992.2	62,000	995.5
5	82,600	995.1	82,600	998.5
10	117,000	998.0	117,000	1002.1
25	127,000	998.6	127,000	1003.0
50	142,900	999.5	142,900	1004.2
100	168,700	1000.8	168,700	1005.7
200	197,200	1002.3	197,200	1007.2

Peak elevation and discharge for the Missouri River (Mile 641 and 645) at the upstream and downstream ends of DeSoto NWR.

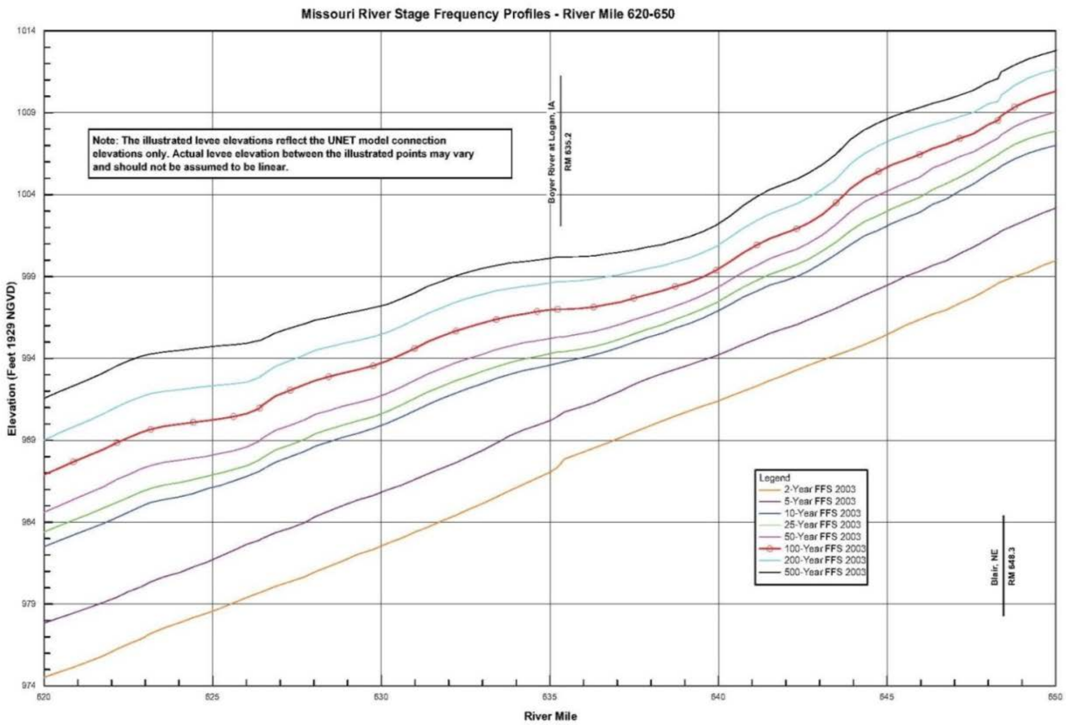


Figure 5-2: USACE Stage Frequency Profile per river mile—DeSoto NWR 641.2–644.6; Boyer Chute NWR 631.2–640.2 (figure from USACE 2003 Upper Mississippi River System Flow Frequency Study)

A map of estimated flood frequencies across both refuges was created as part of DSBCNWR's CCP and is shown on the map below (figure 5-3). Most of the refuges' property is within the 10-year flood elevation, and the southwestern borders of both refuges are generally the most infrequently flooded areas.

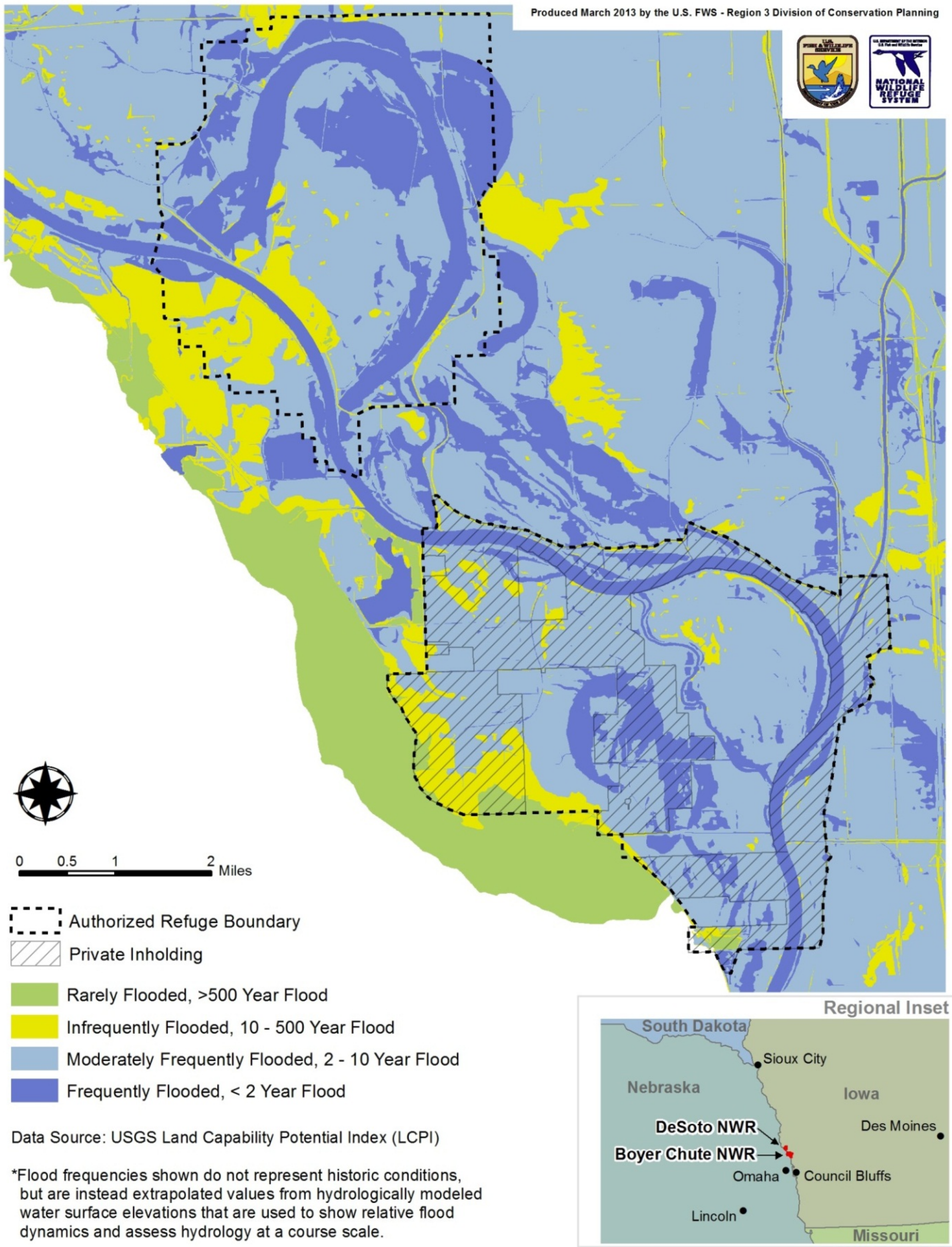


Figure 5-3: Flood frequencies at DeSoto and Boyer Chute NWR (USFWS 2013)

Additional water quantity information is available for the Honey Creek-Missouri River Watershed in the New Stream-reach Development Resource Assessment (http://nhaap.ornl.gov/nsd) as part of the National Hydropower Asset Assessment Program. Some of the measured parameters include average hydraulic head, hydraulic capacity (30 percent exceedance), inundated surface area, reservoir storage, residence time, and flow adjustment ratio.

Groundwater Elevation and Water Quality

Figure 5-4 shows groundwater trends throughout the year for groundwater wells located in the Missouri River floodplain at Blencoe, Iowa (30 miles north of refuges) and Percival, Iowa (60 miles south of refuges). This information suggests that groundwater is typically 6 to 10 feet below ground surface and that levels will typically peak in late May to early June, which is approximately a month after the Missouri River peaks. Based on annual peak discharge trends near Omaha, NE, Missouri River discharge has become noticeably less variable since regulation and management in the 1950s (figures 5-5 and 5-6. In contrast, variability in Boyer River discharge appears to have increased over time (figure 5-7). These high peak flows along with steep gradients and loess soils typical of this ecoregion have made the Boyer River one of the highest and most variable suspended sediment deliverers compared with other tributaries of the Missouri and Mississippi Rivers (USGS 2012). Changes in this river's flow regime may be attributable to the fact that much of it has been channelized and straightened.

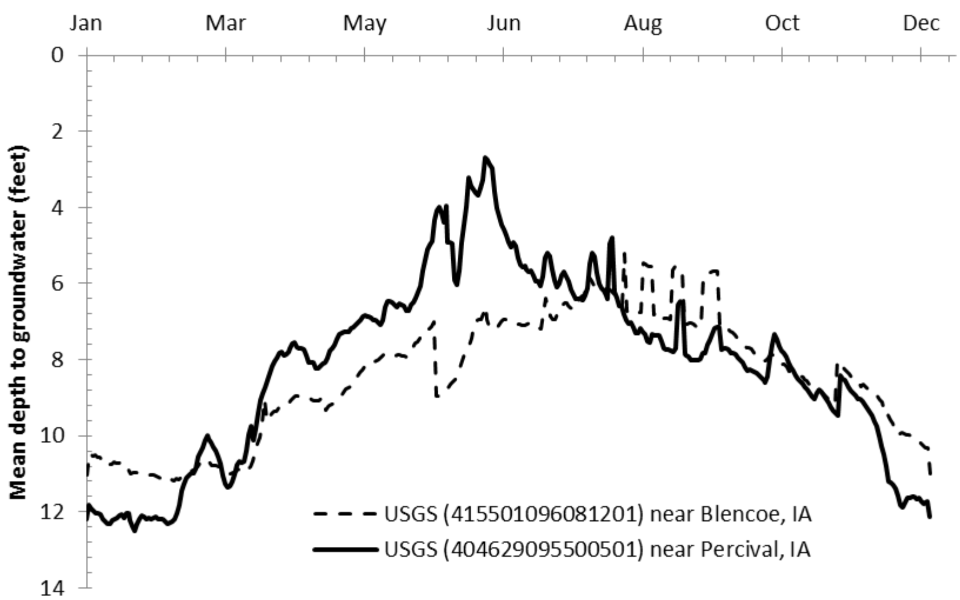


Figure 5-4: Groundwater trends in the area of the refuges (1995–1996 and 2008–2011; USFWS CCP 2013)

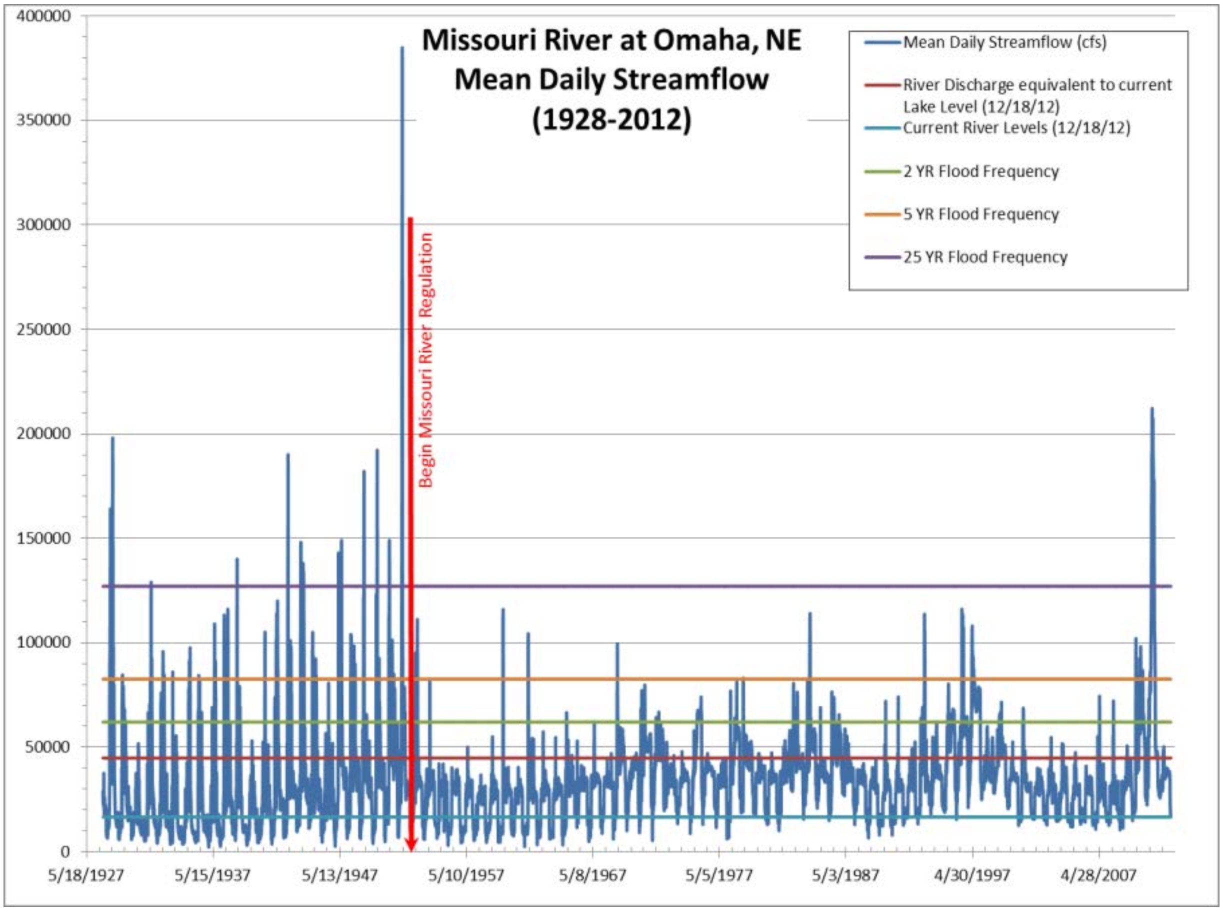


Figure 5-5: Annual peak discharge and current flood frequencies for the Missouri River near Omaha, NE (USGS 0661000)

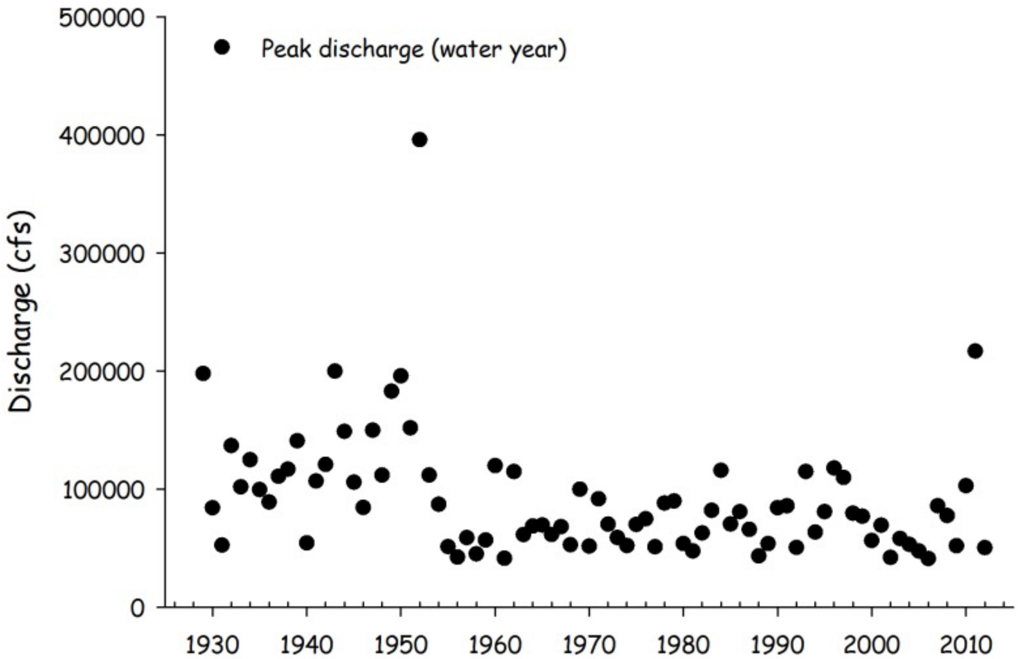


Figure 5-6: Annual peak discharge for the Missouri River near Omaha, NE (USGS 06610000)

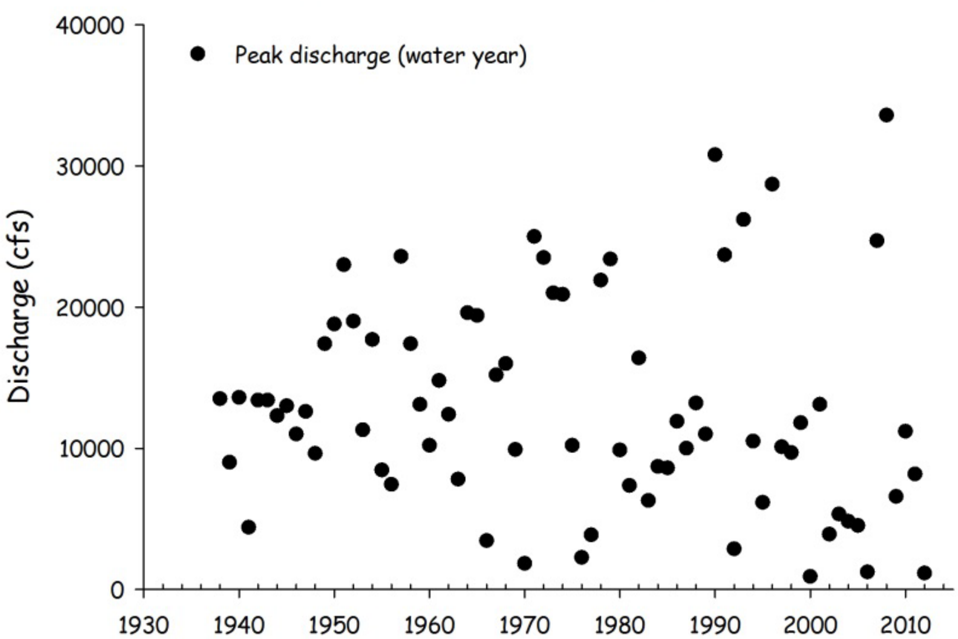


Figure 5-7: Annual peak discharge for the Boyer River near Logan, Iowa (USGS 06609500)

Driller's logs were reviewed for the groundwater wells registered with the State of Nebraska by the refuges. The logs suggest the overlying clay and soil layers are underlain by sand at depths of approximately 10 to 15 feet. Static water levels were often within the 10 to 15 feet range as well. A 30-minute 1200 gallons per minute (gpm) pump test was completed in 1977 at one of the currently abandoned wells, which was used for irrigation. The well demonstrated significant drawdown (approximately 35 feet) during the pump test, suggesting the aquifer may have a low transmissivity, and infiltration rates may be insufficient for aquifer recharge and sustained pumping long-term. However, pump tests at significantly lower rates (i.e., 2 gpm) only demonstrated a drawdown of a couple feet.

A review of the groundwater water quality information found that typically the whole water (e.g., unfiltered or untreated) in the sampled groundwater wells was not appropriate for human consumption. In August 2012, a shallow well (USGS 413003096030201) located west of DeSoto NWR showed levels of nitrate that exceeded 10 milligrams per liter (mg/L) (as nitrogen), which is above the Maximum Contaminant Level for human consumption. It is not clear if the groundwater is an unadvisable source for aquatic life, but levels of iron and manganese could potentially be exceeding values that are appropriate for aquatic life.

There is always the potential for large rivers (e.g., Missouri River) and the saturated vadose zone (shallow zone extending from the ground surface to the water table) surrounding it to act as a hydraulic dam to groundwater flow, causing water to rise up to the surface as seeps and springs. However, there is currently not any evidence that this is happening at the refuges.

Surface Water Quality

Water chemistry information was downloaded from the USEPA STORET database, using the USEPA "Surf your Watershed" (http://cfpub.epa.gov/surf/locate/index.cfm) and the USGS National Water Information System database (http://qwwebservices.usgs.gov/).

305(b) Reporting and 303(d) Assessments

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met based on designated usage. Rivers that border multiple states (e.g., Missouri River) may have conflicting designations and multiple data sources available. The following is a summary of available water quality information and impairments status for water bodies within and/or adjacent to DeSoto and Boyer Chute NWRs.

Missouri River

The Missouri River, from Sioux City, Iowa to Bellevue, NE, did not support primary contact recreation due to levels of indicator bacteria that exceed state water quality standards. In 2007, the USEPA approved a Total Maximum Daily Load (TMDL) for *E. coli* reduction; although, it is not clear if the river is now supporting primary contact subsequent to the TMDL implementation. For reporting year 2004, there were also impairments listed based on elevated Dieldrin and Polychlorinated Biphenyls (PCB) levels, which were removed in 2012. Aquatic life use is only partially supported, based on information from local fisheries biologists, due to impacts from flow modification and habitat alterations in this segment of the Missouri River.

On the Missouri River from the mouth of the Boyer River to Omaha, drinking water standards have not been met due to levels of arsenic, which exceed state water quality requirements to protect human health from arsenic in fish and water.

The water quality of the Missouri River is not an issue that can be improved through the actions of the DeSoto NWR and Boyer Chute NWR staff. Therefore, it is not given substantive evaluation within the WRIA. However, the use of these waters for refuge habitat management should include consideration of any potential threats to fish and wildlife species associated with these contaminants.

DeSoto Bend Lake

DeSoto Lake (also called Desoto Bend Lake) is on the 303(d) list because it only partially supports primary contact recreation (Class A), due to elevated turbidity and algal growth/Chlorophyll a (Chl a). The condition of the lake is described as "aesthetically objectionable," due to trophic state and visibility. The Trophic State Index (TSI) exceeds criteria because visibility is often less than 1 to 2 feet, when measured with a Secchi disk, a common limnology measurement of visibility. TSI can be determined from Secchi disk, total phosphorus (TP) or Chl a concentrations. The variability is these numbers may be indicative of the underlying causes of the eutrophic condition. For example, if Secchi disk readings exceed TP and Chl a TSI, there may be other causes of turbidity then excessive algal growth. Also, eutrophic growth may be limited by other limiting factors if TP TSI exceeds Chl a TSI. The TSI information available for DeSoto Lake suggest that visibility is primarily a function of excessive algal growth and that phosphorus availability is not always the limiting nutrient. It is likely that nitrogen-limitation is also taking place, as evidenced by low nitrogen water column concentrations and blooms of species that can fix nitrogen from the atmosphere.

For 303(d) listing purposes, aesthetically objectionable conditions are present in a water body when the median summer Chl a or Secchi disk depth TSI exceeds 65. In order to de-list a lake impaired by algae from the 303(d) list, the median growing season Chl a TSI must not exceed 63 in two consecutive listing cycles, per Iowa DNR de-listing methodology. To avoid exceeding a TSI value of 63, the median summer Chl a concentration must not exceed 27 micrograms per liter (ug/L)

Assessments have also determined the lake to be suitable to support aquatic life and fish consumption. Contaminants in fish were below fish consumption thresholds, when the lake was last assessed in 1998.

Aside from the 303(d) list, the most recent and most relevant water quality information is available from the Iowa Lakes Information System, which is an Iowa DNR online database (http://limnology.eeob.iastate.edu/lakereport/chemical_report.aspx?ryear=2013&Lake_ID=028&bk=25#25) with data collection and analysis information completed by the Limnology lab at Iowa State University. This data collection effort includes nutrient information, trophic indices, zooplankton, and phytoplankton collections.

It is possible to make some general qualitative conclusions about the health of the DeSoto Lake and the impact of the 2011 flood on the Lake:

- Generally, the data suggests sufficient levels of dissolved oxygen are available for aquatic life; although, measurements were only collected during daytime only sampling events and may not reflect actual diurnal dissolved oxygen fluctuations.
- The lake, subsequent to the 2011 flood, has slightly elevated specific conductance. Typical values of the lake exceeded 500 micro-Siemens per centimeter (µS/cm), which is not unusual in natural waters but may be detrimental to some sensitive species.
- Readily biologically available nitrogen and phosphorus concentrations are low. However, total phosphorus levels are elevated and eutrophic conditions are apparent. Nitrogen fixing bacteria and algae are common.
- DeSoto lake has a relatively high pH (>8), which is unlikely to impact fisheries directly. Values exceeding a pH of 9 would be justification for listing the lake as impaired for pH. However, there are potential chemical speciation ramifications of a relatively alkaline (albeit well-buffered) aquatic environment. The pH will affect the availability of elements for uptake by plants and biota, which can be both positive and negative:
    - If the soils in the lake have a similar pH, there will be reduced availability of phosphorous, nitrogen, and trace minerals for plants.
    - At higher pH, the un-ionized form of ammonia is more profligate. This can lead to ammonia toxicity.
    - Transiently high pH values (>9.0) may be possible from large amounts of photosynthetic activity fueled by eutrophic conditions.
    - At higher pH, the toxicity of iron (apparent in groundwater wells) is reduced, but the toxicity of other metals may be higher, if they are present (i.e., cadmium and aluminum). Information is not available for the concentrations of potentially toxic metals in the lake, but the pH levels suggest that tests for certain metals may be more relevant.

Additionally, the zooplankton and phytoplankton information suggest:

- There has been a significant decrease in large filter feeding zooplankton and in abundance of all species (µg/L of dry mass).
- Sampling in 2012 and 2013 found a negligible population of Cladocera (a previously common zooplankton) and a significant increase in Asplancha, an omnivorous predatory rotifer species.
- There has been an increase in cyanobacteria (blue-green algae) and other eutrophic indicator species such as euglenophyta. There was a cyanobacteria bloom in 2012, which was substantially reduced in 2013.

In conclusion, it is likely eutrophic conditions will continue to persist due to elevated nutrients in sediments. Flood induced changes in fisheries will be persistent and continue to affect zooplankton and phytoplankton populations. Potential remedial activities may include dredging, chemical treatments, or biotic manipulation through the addition of indigenous vertebrate or invertebrate species. Due to the relatively small size of the lake drainage basin, it seems unlikely that upstream best management practice will have a significant effect on eutrophic conditions.

Boyer River

Designated uses along a 29.4 mile segment of the Boyer River, ending at the confluence of the Missouri River, were re-classified from fish consumption and aquatic life usage to include primary contact recreation in 2008. This segment does not support primary recreation because the geometric mean of *E. coli* bacteria (588 organisms/100ml) greatly exceeded the Iowa Class A1 water quality criterion of 126 organisms/100ml, during a 2004–2006 evaluation. The Boyer River has not been assessed for fish consumption but does support aquatic life usage. Levels of dissolved oxygen in the Boyer River were below the threshold (5 mg/L) for aquatic life usage roughly 8 percent of the time, during the sample period. To be considered impaired for aquatic life, levels must be below the threshold in over 10 percent of the samples. This suggests that the river is supporting aquatic life, but very sensitive species are less likely to proliferate.

Currently, the Boyer Chute NWR does not include property adjacent to the Boyer River. However a small portion of the Boyer River is adjacent to land within the acquisition boundary. A cursory evaluation of the most relevant water quality station indicates water quality issues of significant concern. The Boyer River contains high levels of nutrients and sediments and is likely a transport pathway for other contaminants of concern, such as pesticides, during the spring runoff.

Compared to other tributaries of the Missouri and Mississippi Rivers, the Boyer River basin is consistently one of the most significant contributors of suspended sediment and, especially during dry years, orthophosphate (USGS 2012). Atypical of other tributaries in the area, the Boyer River has demonstrated an inverse relationship of orthophosphate concentrations with stream discharge. These concentrations have measured particularly high in recent years (figure 5-8). Nitrate concentrations, however, have been found to be lower than those in other Mississippi and Missouri River tributaries (USGS 2012).

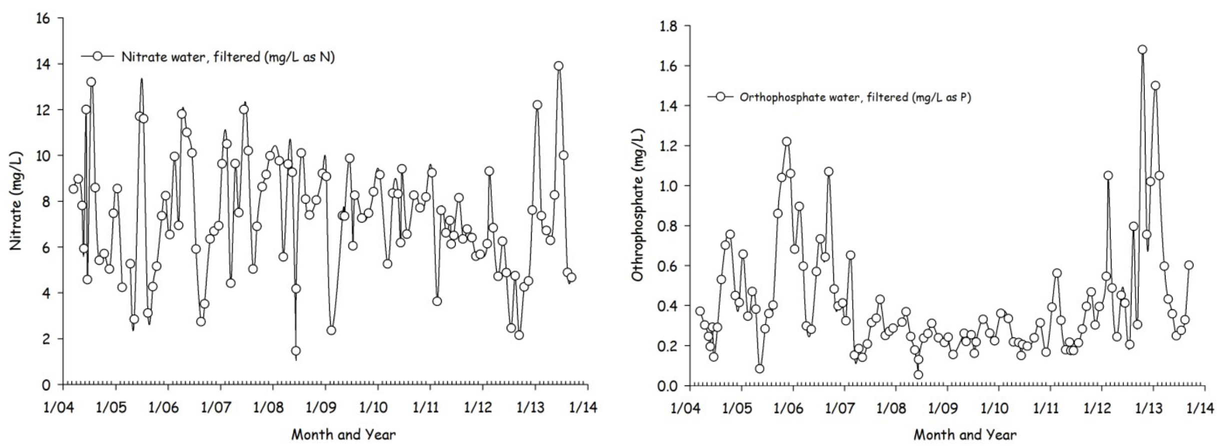


Figure 5-8: Nitrate (left: mg/L) and Orthophosphate (right: mg/L) at Boyer River near Logan, Iowa (USGS 06609500

Deer Creek

Deer Creek is identified is the primary source for the surface water rights located at Boyer Chute NWR. There is not any available water quality information for Deer Creek.

Rand's Ditch, Brown's Ditch, and Brown's Pond

Several vernal pools and small ponds within DeSoto NWR were chosen as part of a broad study to examine the occurrence of glyphosate, atrazine, and other herbicides/pesticides in water resources adjacent to pesticide-managed lands before and after application (Battaglin et al. 2009).

Specifically, a site adjacent to privately managed cropped land (just south of the visitor center) was sampled at DeSoto NWR, as well as Rand's Ditch, Brown's Pond, and Brown's Ditch. Detection of glyphosate and aminomethylphosphonic acid (residual compound) at the wetlands adjacent to the privately-managed land was attributed to origins within the refuge and transport by runoff.

Atrazine was detected at concentrations well above those of previous measurements taken in 1993–1994 at other sampling locations within the refuge (Copeland 1996; ServCat 23206), although samples from this older study were not necessarily taken after herbicide application on adjacent land. Concentrations measured in the 2009 sampling effort were also greater than the freshwater aquatic life standard for atrazine (1.8ug/L) (Battaglin et al. 2009). Many of the other pesticides detected within DeSoto NWR for the study (2,4-Dichlorophenoxyacetic acid, atrazine, benomyl, glyphosate, imazethapyr, metalaxyl, nicosulfuron, oryzalin, and oxamyl) are used on crops in Iowa, so the agricultural lands drained by the ditches are likely sources, although atmospheric deposition and groundwater sources are also probable. Previous studies have detected atrazine in rainwater at DSBCNWR, possibly explaining its presence in water features lacking clear connections to agricultural drainage (Copeland 1996).

Atrazine, nicosulfuron, and triclopyr concentrations detected in the ditch sites were high enough to possibly impair the water quality of DeSoto Lake downstream. The presence of atrazine has been well-documented in DeSoto Lake through previous monitoring, but the additional detection of its residual compounds suggests that it continuously breaks down over time (Copeland 1996).

6. Water Law

The acquisition boundaries for both refuges cross state boundaries in Iowa and Nebraska. The water laws governing these states are based on markedly different water law doctrine, which are generally riparian rights in Iowa and prior appropriation in Nebraska.

Water law in Nebraska is governed by prior appropriation water law, meaning that during shortages, water is appropriated to those individuals and entities that hold the oldest water rights. This is different from Iowa, which governs its water law under riparian water law doctrine and allows equal rights to riparian landowners.

Iowa

Information on water quality standards (chapter 61 of the Iowa Administrative Code) and permitting is available for the Iowa DNR, the primary contact and regulatory authority (see Rule Reference Documents [http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/Rules.aspx]).

Construction, excavation or filling in streams, lakes, wetlands, or on the floodplains may require permits from both the USACE and Iowa DNR. A joint application form should be submitted to both agencies to begin the permit process for any of the following activities (see Wetlands Permitting [http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WetlandsPermitting.aspx]):

- Cutting the bank of a river, stream, or lake
- Any excavation or dredging in a wetland, lake, stream, or river
- Channel changes or relocations (including stream straightening)
- Construction of any permanent dock, pier, wharf, seawall, boat ramp, beach, intake, or outfall structure on a stream, river, or lake
- Placement of any fill, riprap, or similar material in a stream, river, lake, or wetland
- Construction of a dam across any waterway
- Placement of fill; construction of levees, roadways, and bridges; and similar activities on a floodplain; or construction of buildings on a floodplain
- Any construction on, above, or under all fee title lands and waters; dedicated lands and waters under the jurisdiction of the Natural Resource Commission (Commission) and managed by the Commission for public access to a meandered sovereign lake or meandered sovereign river; meandered sovereign lakes; meandered sovereign rivers; and sovereign islands (except those portions of the Iowa River and Mississippi River where title has been conveyed to Charter Cities)

From the DOI Solicitor office:

> *In states that apply the riparian rights doctrine (e.g., Iowa), landowners of property with naturally flowing surface water running through or adjacent to their property have rights to reasonable use of the surface water associated with the property itself. The “reasonable use” standard protects downstream users by ensuring that one landowner’s use does not unreasonably impair the equal riparian rights of others along the same watercourse. Additionally, the law limits riparian rights to those rights “intimately*

associated" with the water; uses falling outside of this definition are usually considered unreasonable uses.

An important corollary to the riparian rights doctrine is that, generally, states classify their navigable surface waters as public, whether through statute or through the common law public trust doctrine. This is important because on public waters, the riparian landowners' rights are subject to public rights of, at a minimum, navigation. For this reason, states regulate waters for the purpose of putting the water to "beneficial use," a term defined differently amongst the states. Like other states in the region, Iowa's stated water policy is to conserve and protect water resources by putting all water to beneficial use, and preventing unreasonable use.[1] The state defines "beneficial use" as one that applies water "to a useful purpose that inures to the benefit of the water user and subject to the user's dominion and control but does not include the waste or pollution of water."[2] While courts have not explicitly announced whether this definition includes instream uses for fish and wildlife, as a refuge manager, FWS certainly puts instream uses to a useful purpose directly associated with the benefits FWS seeks to reap. In order to accomplish this policy, the state gave the authority and duty to the Iowa Department of Natural Resources (DNR) to assess the water needs and prepare a water allocation plan.[3]

Iowa uses a regulated riparian approach by enacting a permit system for "depleting uses," which include diversion, storage, and withdrawal.[4] This permit system applies to public waters, or waters occurring in a "basin"[5] (i.e., aquifers) or "watercourse"[6] (i.e., surface water), and storage and withdrawals from groundwater aquifers.[7] Persons,

---

[1] Iowa Code § 455B.262 (2011).

[2] Iowa Code § 455B. 261 (2011).

[3] Iowa Code § 455B.262 (2011).

[4] Iowa Code §§ 455B.261; 455B.268 (2011).

[5] "Basin" is defined as "a specific subsurface water-bearing reservoir having reasonably ascertainable boundaries." Iowa Code § 455B.261 (2011).

[6] "Watercourse" is defined as a "lake, river, creek, ditch, or other body of water or channel having definite banks and bed with visible evidence of the flow or occurrence of water, except lakes or ponds without outlet to which only one landowner is riparian." Iowa Code § 455B.261 (2011).

[7] Iowa Code § 455B.265 (2011). The statute does not specifically declare public ownership of groundwater resources, but other laws throughout at least cautiously regulate groundwater resources. The policy, however, declares quite clearly the state's interest in ensuring long-term availability of all water resources.

including federal government agencies,[8] using more than 25,000 gallons-per-day must have a permit; any amount below this the state classifies as a "non-regulated use."[9]

DNR issues permits so long as the "established average minimum flow is preserved," and denies permits for uses that will impair: (1) the effect of pollution control laws, (2) navigability of a watercourse, (3) long-term availability of surface or groundwater, or (4) public health or welfare.[10] The permits only last for either ten or twenty-five years depending on the type of permit, and based on the criteria above, DNR may also limit the quantity and time period when withdrawals can be made.[11] Upon receipt of a citizen complaint, DNR will investigate unauthorized withdrawals of a depleting use.[12]

The Iowa Environmental Protection Commission (EPC) determines the average minimum flow (also called "protected flow" in the state's regulations) of the watercourse for which a water user has submitted a permit, and the measurement should be based on the "limit at which further withdrawals would be harmful to the public interest," among other factors.[13] EPC promulgated regulations that include the specific protected flow for numerous rivers, and branches thereof, throughout the state.[14] If a gage located at one of the listed rivers or streams measures flow levels below those in the regulations, then consumptive uses (excepting public water supply consumption) on the river will cease.[15]

Although permits do not establish priority at the time of issuance, the state may, if triggering events occur, "suspend or restrict" both permitted depleting uses and non-regulated uses by implementing a "priority allocation plan."[16] Essentially, these triggering events identify situations when water shortages might occur, and provide four means of notifying DNR that a drought or emergency affecting water resources is

---

[8] Iowa Code § 455B.131(9) (2011).

[9] Iowa Code §§ 455B.261; 455B.268 (2011).

[10] Iowa Code § 455B.267 (2011). Depleting uses occurring prior to the law's enactment in 1985 automatically received permits; however, the state may still restrict these water users during emergency shortages. Iowa Code § 455B.265 (2011).

[11] Iowa Code § 455B.265 (2011). Permits vary based on the type of use, such as irrigation or water storage, and contain more detailed requirements than the baseline set forth in the statutes. See, e.g., IAC §§ 567-38.3, 567-52 et seq. (2011).

[12] Iowa Code § 455B.274 (2011).

[13] Iowa Code § 455B.261 (2011).

[14] IAC § 567-52.8 (2011).

[15] IAC § 567-52.3 (2011).

[16] Iowa Code § 455B.266 (2011).

imminent.[17] Once a triggering event occurs, then DNR restricts water based on the type of use beginning with the lowest water priority, "water conveyed across state boundaries," up to the highest priority, private waters for human consumption.[18] While the priority allocation plan does not list use of water for wildlife purposes, the plan restricts "uses of water for recreational or aesthetic purposes" second in its reverse-priority list, after water conveyed across state lines.[19] Given that recreational and aesthetic purposes also rely on instream flows, it is likely that wildlife purposes would also fall into this type of use, were DNR to implement its priority allocation plan.

The state also provides for other permit or financing programs that may help to protect instream water resources. For example, the state requires permits for dams along its waters and allows local government units to plan for development on floodplains, which are then adopted by the states.[20] It also created a sponsor program for water resource restoration, which provides funds to communities conducting watershed projects. The program specifically identifies projects like "instream habitat enhancements or dam removals," as desirable.[21]

By instituting a comprehensive priority-based permit program, Iowa has taken a significant role in protecting its water resources, and as a result the program will conserve instream flows that will help FWS. Even though the state does not provide FWS a means to insert itself into the permitting system, FWS will still have common law riparian rights that it may assert against other riparian right holders. Further, Iowa and FWS share the same goals of conserving instream water, as shown by its broad definition of beneficial use and the state's policy statements.

---

[17] Iowa Code § 455B.266(a) (2011).

[18] Iowa Code § 455B.266(b) (2011). The DNR will restrict uses in the following order:

a. Water conveyed across state boundaries.
b. Uses of water primarily for recreational or aesthetic purposes.
c. Uses of water for the irrigation of hay, corn, soybeans, oats, grain sorghum or wheat.
d. Uses of water for the irrigation of crops other than hay, corn, soybeans, oats, grain sorghum or wheat.
e. Uses of water for manufacturing or other industrial processes.
f. Uses of water for generation of electrical power for public consumption.
g. Uses of water for livestock production.
h. Uses of water for human consumption and sanitation supplied by rural water districts, municipal water systems, or other public water supplies as defined in section 455B.171.
i. Uses of water for human consumption and sanitation supplied by a private water supply as defined in section 455B.171.

[19] Iowa Code § 455B.266(b) (2011).

[20] Iowa Code §§ 455B.275; 455B.276

[21] Iowa Code § 455B.199 (2011).

Nebraska

A summary of water regulations for the State of Nebraska, as well as associated links, can be found on the University of Nebraska-Lincoln website (see UNL Water [http://water.unl.edu/cropswater/regulations]). Also, the Nebraska Unicameral Legislature website (http://www.nebraskalegislature.gov/index.php) provides a list of the state's surface water, groundwater, and water data collection statutes.

Surface water in Nebraska is governed by prior appropriation law. Groundwater is subject to the correlative rights doctrine, which allows well construction and allocates water under reasonable use. All irrigation wells require permits, which allow withdraw in any necessary quantity as long as it is for beneficial use. These permitted wells must be registered and documented in Nebraska DNR's database (http://data.dnr.nebraska.gov/wells/Menu.aspx), and notification of new ownership, well abandonment, correction of registration information, or well modification is required in writing. Furthermore, wells must be a minimum distance from other separately-owned wells, and wells require permits if they have been installed since 1993 and are either:

- Within 50 feet of a stream or river
- Located in a water management area
- Or purposed for geothermal resource development

In accordance with Nebraska state water law, Boyer Chute NWR maintains five surface water rights and has 10 (three active) wells registered for water withdrawals and diversions (see Appendix C Water Rights Registered in Nebraska). The five surface water rights (842.65 acre–feet/year) and groundwater wells are used primarily for habitat management. One of the registered wells is for the geothermal system for the heating, ventilation, and air conditioning system. Most of these rights are supplemental, meaning the water sources are commingled to supply the refuge needs for optimum operation. The groundwater wells are the primary source because withdrawals are not limited. Boyer Chute is not located within a Nebraska Groundwater Management Area. Groundwater management areas in Nebraska may have additional requirements and regulations governing reporting, withdrawal, and water quality of discharges depending on the status of water appropriation within the region.

Currently, water management activities at DeSoto NWR do not require permitting under Iowa state water regulations (<25,000 gallons per day). Typically, water is neither pumped nor diverted from the portion of the refuge located in Nebraska.

Under legislative bill (LB) 1357 (1972), Natural Resource Districts (NRDs) were created within the state, based on major drainage basins. LB 1357 (1975) gave these districts regulative authority, in conjunction with the Nebraska DNR, over groundwater use, management, development, and conservation. With the passage of LB 108 (1996), which legally acknowledges surface and groundwater connections, NRDs' groundwater management areas are used to regulate conflicts related to hydrologically connected ground and surface water resources. Boyer Chute NWR is not currently located within a groundwater management area, but the Papio-Missouri River NRD (http://www.papionrd.org/) is the entity associated with DSBCNWR's groundwater resources, and under LB 1106 (1985) is required to create groundwater management plans that detail strategies for controlling water use and quality in the district. Specifically, the Papio-Missouri River NRD's plan involves nitrate testing every five years, management area establishment, and chemigation (the application of both water and agrichemicals through irrigation systems) permitting.

The Water Policy Task Force, created under LB 1003 (2002), assessed the policies and water resources of the state in 2003 and recommended changes to Nebraska's water law, which were incorporated into LB 962 (2004). Specifically, the DNR had to conduct water balance assessments for each watershed to classify water resources as under, fully, or over-appropriated (http://dnr.nebraska.gov/Media/iwm/PDF/FullyOverAppropriatedAreaStatewide_0409.pdf). Most of the water supply and demand imbalances are focused in the western portion of the state. Water resources in the Papio-Missouri River NRD were classified as under-appropriated, no banning of new surface water rights or high-capacity wells resulted, and this district is not required to develop an integrated management plan with the Nebraska DNR.

7. Geospatial data

1. The National Wetland Inventory, established by the USFWS, provides seamless wetland and riparian polygon data for download.
2. The NHD is produced as a cooperative effort by the USEPA, the USGS, and other federal and state agencies.
3. HUC polygons are available from the EPA as part of the Watershed Boundary Dataset (WBD). These boundaries were delineated in cooperation with the USGS using methodology adapted from Seaber et al (1987).
4. LiDAR data for the refuges are available from the Iowa DNR and the USACE (Omaha District).
5. An Environmental Systems Research Institute, Inc. (ESRI) shapefile of nontopological geometry and attribute information for spatial features of water monitoring locations is provided through the STORET data warehouse.
6. The National Land Cover Database classifies the United States in 16 unique categories at a 30 meter resolution based on 2006 Landsat satellite data (Fry et al., 2011).
7. The Soil Survey Geographic (SSURGO) dataset was produced by the USDA NRCS with data gathered by the National Cooperative Soil Survey. The database includes taxonomical, texture, drainage, and other soils information in geospatial and tabular formats, and is intended to help guide natural resource planning and management activities (USDA, 2011).
8. Other geospatial data layers were obtained from the U.S. Fish and Wildlife Service, USGS seamless server, the Environmental Protection Agency, and the Missouri Spatial Data Information Services website (http://msdis.missouri.edu/).

8. Literature Cited

Ambrose, S. E. (1997). *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West.* New York: Touchstone.

Berner, L.M. (1951). “Limnology of the Lower Missouri River.” *Ecology 32*(1), 1–12.

Copeland, T.A. (1996).Herbicide and Algal Population Monitoring at DeSoto National Wildlife Refuge. USFWS Region 3 Contaminants Program. Study No. 3N14. 31p.

Elliott, C. M., Jacobson, R. B., and Chojnacki, K. A. (2006). “Hydroacoustic mapping to define sedimentation rates and characterize lentic habitats in DeSoto Lake, DeSoto National Wildlife Refuge.” *U.S. Geological Survey. Open-File Report 2006-1254*, 28p. Available online at: http://pubs.usgs.gov/of/2006/1254/downloads/pdf/OF06-1254.pdf

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Galat, D. L., Berry Jr., C. R., Gardner, W.M., Hendrickson, J.C., Mestl, G.E., Power, G.J., Stone, C., and Winston, M.R. (2005). “Spatiotemporal patterns and changes in Missouri River fishes.” In Rinne J.N., Hughes, R.M., and Calamusso, R. (Eds.). *Historical changes in fish assemblages of large American rivers* (p.249–291)*.* Symposium conducted at the meeting of the American Fisheries Society, Bethesda, Maryland.

Groisman, P.Y., Knight, R.W., Easterling, D.R., Karl, T.R., Hegerl, G.C., and Razuvaev, V.N. (2005). “Trends in intense precipitation in the climate record.” *Journal of Climate, 18*(9), 1326–1350.

Hayhoe, K., Wake, C.P., Huntington, T.G., Luo, L., Schwartz, M.D., Sheffield, J., Wood, E., Anderson, B., Bradbury, J., DeGaetano, A., Troy, T.J., and Wolfe, D. (2007). “Past and future changes in climate and hydrological indicators in the U.S. Northeast.” *Climate Dynamics, 28*(4), 381–407.

Hesse, L. W. (1987). “Taming the wild Missouri River: what has it cost?.” *Fisheries, 12*(2), 2–9.

Interagency Advisory Committee on Water Data (IACWD). (1982*). Guidelines for Determining Flood Flow Frequency* (Bulletin No. 17B). 194.

Iowa Climate Change Impacts Committee (ICCIC). (2011).”Climate Change Impacts on Iowa: Report to the Governor and the Iowa General Assembly.” Available online: http://www.iowadnr.gov/portals/idnr/uploads/air/environment/climatechange/complete_report.pdf?amp;tabid=1077

Iowa Department of Natural Resources. (2012). “DeSoto Bend Lake.” *Iowa Department of Natural Resources – Iowa Geologic and Water Survey – Watershed Monitoring and Assessment.* Website accessed 15 November 2012 at http://www.igsb.uiowa.edu/wqm/Lakes/LakeWatershedCharacteristics/desotobend.htm

Jacobson, R. B., Chojnacki, K. A., and Reuter, J. M. (2007). "Land capability potential index (LCPI) for the Lower Missouri River Valley." *U.S. Geological Survey Scientific Investigations Report* 2007-5256, 19.

Johnson, K., Babij, E., Fris, R., Freund, K., Hudson, M. and Miller, L. (2013). "Highlights of the IPCC 5th Assessment Report: The Physical Science Basis of Climate Change (WGI) Summary for Policymakers & Implications for the US Fish and Wildlife Service." Available online: http://www.fws.gov/home/climatechange/pdf/IPCC-Highlights-Full-Version-for-FWS.pdf?utm_source=Climate+Update+Draft+December&utm_campaign=1st+Climate+Update&utm_medium=email

Lambert, R.B. (1992). "The Ground-Water-Level Monitoring Network in Iowa. U.S. Geological Survey." *Open-File Report* 92-27, 37. Available online at: http://pubs.usgs.gov/of/1992/0027/report.pdf

Magness, D. R., Morton, J.M., Huettmann, F., Chapin III, F.S., and McGuire, A.D. (2011). "A climate-change adaptation framework to reduce continental-scale vulnerability across conservation reserves." *Ecosphere 2*(10), 112.

Menne, M.J., Durre, I., Vose, R.S. , Gleason, B.E., and Houston, T.G. (2012) "An overview of the Global Historical Climatology Network-Daily database." *Journal of Atmospheric and Oceanic Technology*, **29**, 897–910,doi:10.1175/JTECH-D-11-00103.1

National Oceanic and Atmospheric Administration (NOAA). (2011). "Palmer Drought Severity Index." National Oceanic and Atmospheric Administration, National Climatic Data Center: Asheville, NC. Website accessed 18 April 2011 at: http://lwf.ncdc.noaa.gov/temp-and-precip/time-series/

National Oceanic and Atmospheric Administration (NOAA). (2013). Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 3. Climate of the Midwest U.S. by Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, S.D. Hilberg, M.S. Timlin, L. Stoecker, N.E. Westcott, and J.G. Dobson. NOAA Technical Report NESDIS 142-3, 95 pp.

National Research Council. 2002. The Missouri River Ecosystem: Exploring the Prospects for Recovery. National Academies Press. 175 p.

National Research Council. 2011. Missouri River Planning: Recognizing and Incorporating Sediment Management. National Academics Press. 152 p.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., and Kassem, K. R. (2001). "Terrestrial Ecoregions of the World: A New Map of Life on Earth." *Bioscience* 51:933–938.

Omernik, J.M. (1995). "Ecoregions – a environmental management." In Davis, W.S. and Simon, T.P. (Eds.), *Biological assessment and criteria-tools for water resource planning and decision making* (49–62). Boca Raton, Florida: Lewis Publishers.

Omernik, J.M. (2004). “Perspectives on the nature and definitions of ecological regions.” *Environmental Management*, 34(1), s27–s38.

Palmer, W. C. (1965). “Meteorological Drought. U.S. Weather Bureau, Office of Climatology: Washington D.C. Research Paper No. 45.” Available online at: http://lwf.ncdc.noaa.gov/temp-and-precip/drought/docs/palmer.pdf

Pinter, N. and Heine, R.A. (2005). “Hydrodynamic and morphodynamic response to river engineering documented by fixed-discharge analysis, Lower Missouri River, USA.” *Journal of Hydrology*. *302*(1–4), 70–91.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., and Stromberg, J.C. (1997). “The natural flow regime: A paradigm for river conservation and restoration.” *Bioscience*, 47(11):769–784.

Union of Concerned Scientists (UCS). (2009). “Confronting climate change in the U.S. Midwest - Missouri.” Cambridge, MA: UCS Publications. Retrieved from http://www.ucsusa.org/assets/documents/global_warming/climate-change-missouri.pdf

United States Army Corps of Engineers and United States Environmental Protection Agency. (2002). “The Missouri River Ecosystem: Exploring the Prospects for Recovery.” Washington D.C: The National Academies Press, 176. Retrieved from http://www.nap.edu/openbook.php?record_id=10277

United States Army Corps of Engineers. (2012). “Missouri River Stage Trends Technical Report.” Missouri River Basin Water Management Division, Omaha, Nebraska. 46. Retrieved from http://www.nwd-mr.usace.army.mil/rcc/reports/pdfs/MRStageTrends2012.pdf

United States Department of Agriculture. (2008). “The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States” by Lettenmaier, D., Major, D., Poff, L., and Running, S. (Synthesis and Assessment Product 4.3). Washington, DC: U.S. Climate Change Science Program, 121–150.

United States Department of Agriculture – Natural Resources Conservation Service. (2011). Soil Survey Geographic (SSURGO) Database for Washington County, Nebraska; Pottawattamie County, Iowa; and Harrison County, Iowa – Online Series Descriptions. Accessed 17 June 2011 at: http://soildatamart.nrcs.usda.gov

United States Fish and Wildlife Service. (2010a). “Operational Blueprint for Inventory and Monitoring on National Wildlife Refuges: Adapting to Environmental Change.” 45.

United States Fish and Wildlife Service. (2010b). “Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change.” 56.

United States Fish and Wildlife Service. (2011). “Rising to the urgent challenge: strategic plan for responding to accelerating climate change.” 36.

United States Fish and Wildlife Service. (2013). “DeSoto and Boyer Chute National Wildlife Refuges Environmental Assessment and Draft Comprehensive Conservation Plan.” 361.

United States Geological Survey. (1964). “Geology of the Omaha-Council Bluffs Area Nebraska-Iowa” by Miller, R.D. (USGS Professional Paper 472, prepared as part of a program of the Department of Interior for the development of the Missouri River basin). Washington, DC: U.S. Government Printing Office. 74.

United States Geological Survey. (1987). *Hydrologic Unit Maps* by Seaber, P.R., Kapinos, F.P., and Knapp, G.L. (Water-Supply Paper No. 2294). 63.

United States Geological Survey. (2001). “The Evolution of the Lower Missouri River: A Discussion of the Geology and a Proposal for Research at Lisbon Bottom” by Spooner, J. (Open File Report No. 01-176). 19 .

United States Geological Survey. (2006). “Geomorphic classification and assessment of channel dynamics in the Missouri National Recreational River, South Dakota and Nebraska” by Elliot, C.M. and Jacobson, R.B. (Scientific Investigation Report No. 2006-5313), 66.

United States Geological Survey. (2012). “Concentrations, Loads, and Yields of Select Constituents from Major Tributaries of the Mississippi and Missouri Rivers in Iowa, Water Years 2004–2008” by Garrett, J.D. (Scientific Investigations Report 2012-5240), 61.

Slack, J.R. and J.M. Landwehr. (1992). “Hydro-Climatic Data Network (HCDN): A U.S. Geological Survey Streamflow Data Set for the United States for the Study of Climate Variations, 1874–1988,” U.S. Geological Survey Open-File Report 92-129.

Zohrer, J. J. (2006). “Securing a Future for Fish and Wildlife: A Conservation Legacy for Iowans” (May 2006 Revision). Iowa Department of Natural Resources: Des Moines, Iowa.

9. Additional Hydrologically Applicable References from CAP, CCP

Hansen, M. D. (1972). “The Seasonal Diversity of Microorganisms in Channelized and Unchannelized Portions of the Missouri River” (M.A. thesis, University of South Dakota, Vermillion). 130p. Available from WorldCat database (OCLC Number 9288082).

Huggins, D.G. (1968*). “*Limnology of DeSoto Bend Lake” (M.S. thesis, Iowa State University, Ames). 98. Available from WorldCat database (OCLC Number 26617776).

Johnson, M.R. (1979). “The Limnological Characteristics and Management of Four Western Iowa Oxbow Lakes (including DeSoto)” (M.S. thesis, Iowa State University, Ames). 422.

Missouri Department of Conservation. (1989). “Fish contaminant study of the Missouri and Mississippi Rivers. Final Report” by Bush, J. and Grace, T.B. 15.

Missouri Department of Natural Resources. (2006). “Water quality in Missouri’s larger rivers” by Carter, N.T. and Ford, J. Retrieved from http://www.dnr.mo.gov/pubs/pub2020.pdf

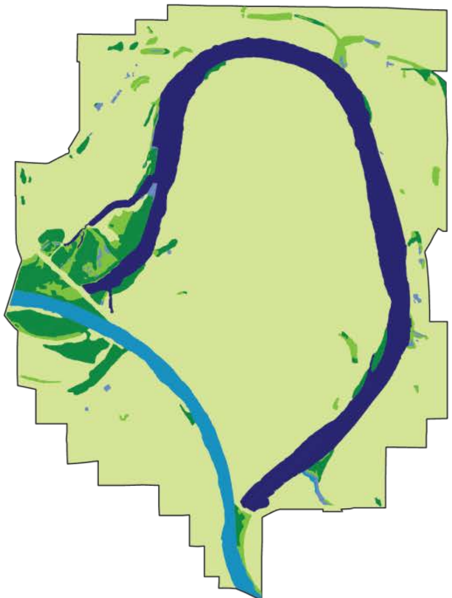
Nebraska Game and Parks Commission and United States Army Corps of Engineers. (1994). “The Morphometry, Macroinvertebrates, and Ichthyofauna of the Restored Boyer Chute: Missouri River, Nebraska” by Hesse, L. W., Thompson, M.R., and Hatcliff, M.J. Omaha District: Project Development Branch. 83.

Schwarz, M. and Lydick, C. (2007). “Laboratory and Field Evaluation of Atrazine and Selenium Exposure and Effects to Pallid Sturgeon (Scaphirhynchus albus): Implications for Recovery Actions within the Platte River Section of Recovery Priority Management Area 4 and Boyer Chute National Wildlife Refuge. Grand Island, Nebraska”: Nebraska Ecological Services Field Office.

Appendix A National Wetland Inventory

Desoto NWR and Boyer Chute NWR
National Wetland Inventory

Source: U.S. Fish and Wildlife Service National Wetland Mapper, The National Map
Projection: NAD 83 UTM 15N



DeSoto NWR

Acquired Boundary

WETLAND TYPE	ACRES	PERCENT
Lake	844.52	10.09%
Freshwater Forested/Shrub Wetland	422.77	5.05%
Riverine	254.12	3.03%
Freshwater Emergent Wetland	204.31	2.44%
Freshwater Pond	36.45	0.44%
Total Classified Wetland Units	1,762.18	21.04%
Acquired Boundary Total Acres	8,373.49	100.00%

CLASS	ACRES
L1UBH	40.23
L1UBHh	801.20
L2USAh	3.09
PEMA	26.00
PEMAd	19.25
PEMAh	32.64
PEMAx	1.92
PEMC	81.52
PEMCh	21.29
PEMCx	1.86
PEMF	16.39
PEMFh	3.44
PFO1A	61.98
PFO1Ad	5.01
PFO1Ah	32.33
PFO1C	23.96
PFO1Cd	4.59
PFO1Ch	12.85
PFOA	126.70
PFOC	26.46
PSS1A	21.07
PSS1Ah	31.63
PSS1C	10.60
PSS1Ch	30.75
PSS1Cx	0.33
PSSA	9.81
PSSAh	14.30
PSSC	10.39
PUBF	6.91
PUBFh	1.38
PUBFx	4.36
PUBG	3.74
PUBGh	5.12
PUBGx	1.85
PUBH	0.03
PUSAh	7.21
PUSC	1.02
PUSCd	2.11
PUSCh	2.73
R2UBH	251.24
R2USA	0.15
R2USC	2.73
Total	1,762.18

Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Lake
Riverine

N
0 1 2 miles

Boyer Chute NWR

Acquired Boundary

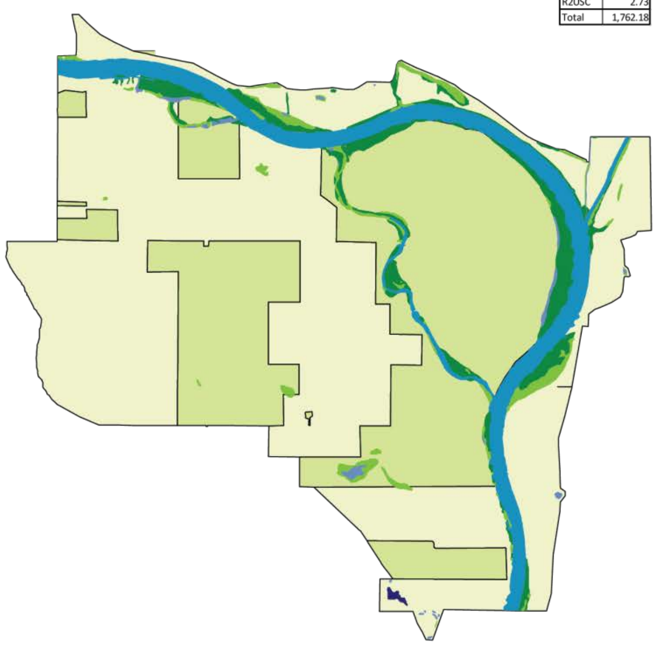
WETLAND TYPE	ACRES	PERCENT
Freshwater Forested/Shrub Wetland	207.03	5.18%
Riverine	75.61	1.89%
Freshwater Emergent Wetland	70.75	1.77%
Freshwater Pond	26.78	0.67%
Lake	0	0.00%
Total Classified Wetland Units	380.17	9.51%
Acquired Boundary Total Acres	3,995.68	100.00%

CLASS	ACRES
PABF	7.47
PEMA	7.79
PEMC	38.49
PEMF	24.47
PFOA	34.44
PFOC	63.91
PSSC	108.68
PUBF	18.64
PUBFx	0.67
R2UBG	41.35
R2UBH	34.26
Total	380.17

Approved Expansion Boundary

WETLAND TYPE	ACRES	PERCENT
Riverine	659.45	11.06%
Freshwater Forested/Shrub Wetland	170.54	2.86%
Freshwater Emergent Wetland	113.63	1.91%
Freshwater Pond	13.38	0.22%
Lake	6.40	0.11%
Total Classified Wetland Units	963.40	16.16%
Expansion Boundary Total Acres	5,962.46	100.00%

CLASS	ACRES
L1UBHx	6.40
PEMA	24.39
PEMAd	1.67
PEMAx	1.09
PEMC	53.76
PEMCx	0.71
PEMF	32.01
PFO1A	96.35
PFO1C	14.28
PFOA	0.11
PFOC	14.00
PSS1A	21.55
PSS1C	0.71
PSSC	23.55
PUBF	2.78
PUBFx	7.69
PUBG	0.71
PUBGx	2.20
R2UBG	0.02
R2UBH	642.01
R2UBHx	15.32
R2USC	2.10
Total	963.40



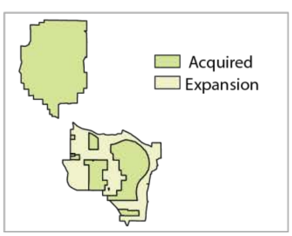


Figure A-1: National Wetland Inventory for DSBCNWR

Appendix B Water Monitoring Sites (STORET)

Table B-1: Active water monitoring sites

Description	ID and Link	Location	Depth/Flood stage	Elevation	Notes	Owner
Missouri River at Sioux City, Iowa (1928–Present)	USGS 06486000	Latitude 42°29'09", Longitude 96°24'49" NAD27	NWS flood stage: 30 ft. Record flood peak, pre-regulation: 441,000 cfs at 24.28 ft. (4/14/1952); Post regulation: 192,000 cfs at 35.24 ft. (7/20/2011)	Drainage area 316,200 square miles; Gage zero datum 1,010ft. NGVD 1929	This site has comprehensive water chemistry (1971–Present).	Record for this site is maintained by the USGS Iowa Water Science Center.
Missouri River at Decatur, NE (1987–Present)	USGS 06601200	Latitude 42°00'26", Longitude 96°14'29" NAD27	NWS flood stage: 35 ft. Record flood peak: 191,000 cfs at 40.03 ft. (6/28/2011)	Drainage area 314,600 square miles; Gage zero datum 1,056.29 ft. NGVD 1929	This site has only sporadic water chemistry data available.	Record for this site is maintained by the USGS Iowa Water Science Center.
Missouri River at Blair, NE (1952?–Present)	USGS 06609100	Latitude 41°33'02", Longitude 96°05'47" NAD83	NWS flood stage:26.5 ft. Record flood peak, pre-regulation: 33.50 ft. (4/17/1952); Post regulation: 32.73 ft. (6/29/2011)	Drainage area 321,400 square miles; Gage zero datum 977.44 ft. NGVD 1988	This site is a stage only site.	Record for this site is currently maintained by the USGS Iowa Water Science Center. Maintained by USACE prior to 2011.
Missouri River at Omaha, NE (1928–Present)	USGS 06610000	Longitude: 95°55'20", Latitude: 41°15'32" NAD27	NWS flood stage: 30 ft. Record flood peak, pre-regulation: 396,000 cfs at 30.20 ft. (4/18/1952); Post regulation: 192,000 cfs at 36.29 ft. (7/02/2011)	Drainage area 322,800 square miles; Gage zero datum 948.24ft. NGVD 1929	This site has comprehensive water chemistry (1968–Present).	Record for this site is maintained by the USGS Iowa Water Science Center.

DeSoto Bend Lake (2000–Present)	IA DNR 22430001	Latitude: 41.5380740, Longitude: -95.998315 NAD83	Elevation 986 ft.	Gage Zero: 421.81 ft. NGVD29	Water quality monitoring site associated with Clean Water Act monitoring.	Monitoring is conducted by the Iowa DNR.
Boyer Chute Groundwater wells (3 clustered)	USGS 412637095565901 USGS 412637095565902 USGS 412637095565903	Latitude 41°26'37", Longitude 95°56'59" NAD83	Well depth: 100 ft., 60 ft., 25 ft.	Land surface altitude: 995 ft. (NGVD29)	This site has comprehensive groundwater level and water chemistry data (1999–2012)	Record for this site is maintained by the USGS Nebraska Water Science Center

Table B-2: Inactive or indirectly relevant monitoring stations

ID	Alternate ID	Sample Type	Surface Water Name	Active?	Notes	Within boundary?
USGS-06609220	N/A	Stream	Allen Creek near Loveland, Iowa	N	14 streamflow measurements, 1957–1976; 4 WQ samples, 1970–1976	N
USGS-06609950	N/A	Stream	Pigeon Creek near Crescent, Iowa	N	13 streamflow measurements, 1957–1975; 3 WQ samples, 1970–1975	N
USGS-06609800	N/A	Stream	Missouri River near Mormon Bridge at Omaha, NE	N	37 WQ/chem samples, 1974–1975	N
USGS-411855095551901	N/A	Well	N/A	N	7 water chem/metal samples	N
USGS-411928095564501	N/A	Facility: Combined sewer	N/A	N	7 water chem samples, 2006–2007	N
USGS-412126095565201	N/A	Stream	Missouri River at NP Dodge Park at Omaha, NE	Y	46 water chem/metal samples, 2006–2013	N
USGS-412259095564601	N/A	Well	N/A	N	1 WQ sample, 2001	N
USGS-412557095564101	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007	Y
USGS-412559096005601	N/A	Well	N/A	N	3 water chem/metal samples, 1992–2001	N
USGS-412629096053001	N/A	Well	N/A	N	1 WQ sample, 1992–2000	N
USGS-412643096012401	N/A	Well	N/A	N	1 WQ sample, 1998	N
USGS-412648095563101	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007	Y
USGS-412652095563601	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007	Y
USGS-412714095572101	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007	Y
USGS-412716095584201	N/A	Well	N/A	N	4 WQ samples, 1995–2004	Y
USGS-412732095592201	N/A	Well	N/A	N	2 WQ/nutrient samples, 2007–2010	Y
USGS-412735095570101	N/A	Well	N/A	N	2 water chem samples, 1992–2004	Y
USGS-412833096034401	N/A	Well	N/A	N	1 WQ sample, 1997	N
USGS-413356096054102	N/A	Well	N/A	N	3 WQ/pesticide/herbicide samples, 1994-1998	N
USGS-413455096095901	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007	N
USGS-413542096063301	N/A	Well	N/A	N	1 WQ/nutrient sample, 2007; 2 water chem/metal samples, 2010–2012	N
21NEB001_WQX-LMT1MILPRK03	N/A	Lake	Miller Park Lake (Omaha) -- Site 03	N	21–22 WQ, E. coli samples, 2010	N
COEOMAHA_WQX-MORRR0619B	N/A	River/Stream	Missouri River	N	1–84 WQ, metal, pesticide/herbicide samples, 2004-2009	N
EMAP_GRE-GRW04449-589	N/A	River/Stream	Missouri River: Lower	N	1–90 water chem, pesticide/herbicide, macroinvertebrate samples, 2004	N
EMAP_GRE-GRW04449-597	N/A	River/Stream	Missouri River: Lower	N	1–90 water chem, pesticide/herbicide, macroinvertebrate samples, 2004	Y
EMAP_GRE-	N/A	River/Stre	Missouri River:	N	1–90 water chem,	N

GRW04449-605		am	Lower		pesticide/herbicide, macroinvertebrate samples, 2004	
EMAP_GRE-GRW04449-613	N/A	River/Stream	Missouri River: Lower	N	1–90 water chem, pesticide/herbicide, macroinvertebrate samples, 2004	N
EMAP_GRE-GRW04449-641	N/A	River/Stream	Missouri River: Lower	N	1–90 water chem, pesticide/herbicide, macroinvertebrate samples, 2004	N
EMAP_GRE-GRW04449-649	N/A	River/Stream	Missouri River: Lower	N	1–90 water chem, pesticide/herbicide, macroinvertebrate samples, 2004	Y
IOWATER-978036	IOWATER_WQX-978036	River/Stream	Allen Creek	N	1 WQ/ambient condition sample, 2005	N
1117MBR-010005	N/A	Lake	DeSoto Bend Lake near Missouri Valley, Iowa	N	1 fish, WQ, pesticide/herbicide sample, 1998	Y
21IOWA-10430001	21IOWA_WQX-10430001	River/Stream	Boyer River near Missouri Valley	N	1–116 WQ, pesticide/herbicide samples, 1999–2009; 1–155 WQ, pesticide/herbicide samples, 1999–2012	N
21IOWA-16780002	21IOWA_WQX-16780002	River/Stream	Boyer River – Missouri Valley – REMAP #74	N	2–4 WQ samples, 2003	Y
21IOWA-22430001	N/A	Lake	DeSoto Bend Lake	N	1–26 WQ, pesticide/herbicide samples, 2005–2008	N
21IOWA-31430003	N/A	Well	N/A	N	1–2 water chem, pesticide/herbicide samples, 2004	N
21IOWA_WQX-22430001	N/A	Lake	DeSoto Bend Lake	N	1–83 water chem, pesticide/herbicide samples, 2000–2012	N
21IOWA_WQX-31430003	N/A	Well	N/A	N	1–2 water chem, pesticide/herbicide samples, 2004	N
EMAP_GRE-GRW04449-633	N/A	River/Stream	Missouri River: Lower	N	1–81 macroinvertebrate, WQ, pesticide/herbicide samples, 2005	N
IOWATER-943003	IOWATER_WQX-943003	River/Stream	Christy 1	N	2 WQ samples, 2001	N
NARSTEST-FW08IA047	N/A	River/Stream	Boyer River	N	1–4 macroinvertebrate/WQ samples, 2009	N
Catalog #6050026	(Sample M60)	River/Stream	DeSoto Bend Lake	N	1 fish tissue sample, 1992	Y
Catalog #6050148	(Sample SS7)	River/Stream	(ECDMS mapper)	N	1 fish tissue/egg sample for metals, 2007	Y

Appendix C Water Rights Registered in Nebraska

Table C-1: Surface water rights at Boyer Chute NWR

Refuge	Section	Township	Range	App #	Establishment Date	Right ID	Use	Active?	Source	Facility Name	Grant	Rate that can be pumped (gpm)
Boyer Chute	20	17N	13E	A-18360	11/18/2005	9979	Storage	Y	Deer Creek	Horseshoe Lake Phase 1	106.95 acre-feet	N/A
Boyer Chute	21	17N	13E	A-17981	5/2/2001	9633	Wetlands	Y	Deer Creek	Pump	1cfs	448
Boyer Chute	21	17N	13E	A-17980	5/2/2001	9695	Storage	Y	Deer Creek	Nathans Lake	65 acre-feet	N/A
Boyer Chute	21	17N	13E	A-18108	10/1/2002	9704	Wetlands	Y	Deer Creek	Omaha Riverfront Redev. Mitigation Site	10.4cfs	4667
Boyer Chute	21	17N	13E	A-18109	10/1/2002	9705	Storage	Y	Deer Creek	Omaha Riverfront Redev. Wetland Mitigation	9.1 acre-feet	N/A

Table C-2: Groundwater rights at Boyer Chute NWR

Refuge	Section	Township	Range	Well ID	Location	Use	Status
Boyer Chute	21	17N	13E	90162	41° 25' 49.00" 95° 57' 46.00"	Domestic	Abandoned
Boyer Chute	9	17N	13E	151349	41° 27' 13.70" 95° 57' 20.30"	Domestic	Abandoned
Boyer Chute	8	17N	13E	179390	41° 27' 31.68" 95° 58' 38.22"	Domestic	Active
Boyer Chute	17	17N	13E	196238	41° 26' 58.40" 98° 58' 33.80"	Domestic	Unregistered Abandoned
Boyer Chute	8	17N	13E	202046	41° 27' 31.60" 95° 58' 38.90"	Lake Supply, Fountain, Geothermal, Wildlife, Wetlands, Recreation, Plant & Lagoon, Sprinkler, Test	Active
Boyer Chute	9	17N	13E	65666	41° 27' 22.67" 95° 56' 49.61"	Irrigation	Abandoned
Boyer Chute	9	17N	13E	92155	41° 27' 3.62" 95° 57' 0.01"	Domestic	Abandoned
Boyer Chute	8	17N	13E	204117	41° 27' 31.67" 95° 58' 36.34"	Ground Heat Exchanger well - Closed Loop Heat Pump well	Active

Division of Biological Resources, Region 3
5600 American Blvd. West, Suite 990
Bloomington, MN 55437-1458

U.S. Fish and Wildlife Service
http://www.fws.gov

Region 3, U.S. Fish and Wildlife Service
http://www.fws.gov/midwest